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PTPLU - A Single Source Gaussian Dispersion Algorithm. User's Guide

Aerocomp, Inc., Costa Mesa, CA

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PTPLU - A SINGLE SOURCE GAUSSIAN DISPERSION ALGORITHM

User's Guide

by

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AFFILIATION

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FOREWORD

Within the Office of Air, Land, and Water Use, the Environmental Sciences Research Laboratory conducts a research program in the physical sciences to detect, define, and quantify the effects of air pollution on urban, regional, and global atmospheres and the subsequent impact on water quality and land use. This includes research and development programs designed to quantitate the relationships between emissions of pollutants from all types of sources, air quality, and atmospheric effects.

The Meteorology and Assessment Division conducts research programs in environmental meteorology to describe the roles and interrelationships of atmospheric processes and airborne pollutants in effective air, water, and land resource management. Developed air quality simulation models (in the FORTRAN computer language) are made available to dispersion model users in computer-readable form by availability of a magnetic tape from NTIS (see preface).

PTPLU is a dispersion algorithm made available in 1981. The program is based upon Gaussian dispersion concepts of steady-state modeling. Limitations are imposed on use of the algorithm by the assumptions that pollutants are nonreactive and that one wind vector and one stability class are representative of the area being modeled. Despite these limitations, PTPLU provides a useful short-term algorithm to obtain the highest concentration and corresponding distance for point sources.

K. L. Demerjian
Director
Meteorology and Assessment Division

PREFACE

One area of research within the Meteorology and Assessment Division is development, evaluation, validation, and application of models for air quality simulation, photochemistry, and meteorology. The models must be able to describe air quality and atmospheric processes affecting the dispersion of airborne pollutants on scales ranging from local to global. Within the Division, the Environmental Operations Branch adapts and evaluates new and existing meteorological dispersion models and statistical technique models, tailors effective models for recurring user application, and makes these models available through EPA's UNAMAP system.

PTPLU is a screening model that uses Gaussian plume modeling techniques. PTPLU is designed for low-cost, detailed screening of point sources to determine maximum one-hour concentrations and also to determine if it is necessary to use one of the more intricate models.

Although attempts are made to thoroughly check computer programs with a wide variety of input data, errors are occasionally found. Revisions may be obtained as they are issued by completing and sending the form on the last page of this guide.

This document is divided into three parts. Sections 1 through 3 are directed to managers and project directors who may wish to become acquainted with the model. Sections 4 and 5 are directed to engineers, meteorologists, and other scientists who are required to become familiar with the workings of a model. Since a number of nonmeteorologists will be using this screening model, Appendix A, Modeling Concepts, presents some of the basic concepts of air pollution meteorology. Together with a Glossary, this should provide the less-experienced user sufficient background to apply the model. Finally, sections 6, 7, and 8 are directed to programmers and data processing professionals, who are often required to implement and run the model. These sections employ the standard terminology of the computer industry.

Comments and suggestions regarding this publication should be directed to

Chief, Environmental Operations Branch
Meteorology and Assessment Division (MD-80)
Environmental Protection Agency
Research Triangle Park, NC 27711.

Technical questions regarding use of the model may be asked by calling (919) 541-4564. Users within the Federal Government may call FTS 629-4564. Copies of the user's guide are available from the National Technical Information Service (NTIS), Springfield, VA 22161.

The magnetic tape containing FORTRAN source code for PTPLU is contained (along with other dispersion models) in UNAMAP (Version 4), which may be ordered as PB 81 164 600 from Computer Products, NTIS, Springfield, VA 22161 (phone number: (703) 487-4763).

ABSTRACT

PTPLU (from PoinT PLUme) is an improved model for estimating the location of the maximum short-term concentration from a single point source as a function of stability and wind speed. The algorithm is similar to PTMAX, which was first released in May 1973. Among the improvements in this version are options for the estimation of gradual plume rise, stack downwash, and buoyancy-induced dispersion. Maximum concentrations and their corresponding downwind distances are calculated for two sets of wind speeds: winds assumed to be constant with height and winds assumed to increase with height. For the latter case, wind speed is extrapolated from anemometer height to stack top using a power-law wind profile. PTPLU is based on the point-source solutions of the Gaussian plume equations. It uses Briggs' plume rise equations, Pasquill stability classes, and Pasquill-Gifford dispersion parameters. Multiple reflections are considered until the vertical dispersion parameter is 1.6 times the mixing height; uniform mixing is assumed thereafter. No fumigation or chemical reactions are considered. A built-in test example is provided with the interactive version of the program. This document describes the input, processing, and output of both the batch and interactive versions of the program.

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SYMBOLS AND ABBREVIATIONS

Dimensions are abbreviated as follows:
m = mass, l = length, t = time, τ = temperature.

d	-- stack inside diameter (l)
F	-- buoyancy flux parameter (l^4/t^3)
g	-- acceleration due to gravity (l/t^2)
H	-- effective height of plume (l)
h	-- stack height above ground (l)
h'	-- stack height adjusted for stack downwash (l)
L	-- mixing height (l)
p	-- wind-profile exponent
Q	-- emission rate (m/t)
s	-- stability parameter (t^{-2})
T	-- ambient air temperature (τ)
T_s	-- stack gas temperature (τ)
u	-- wind speed at stack top (l/t)
v_s	-- stack gas exit velocity (l/t)
x	-- downwind distance (l)
x_f	-- distance to final rise (l)
x^*	-- distance at which atmospheric turbulence begins to dominate entrainment (l)
y	-- crosswind distance (l)
z	-- receptor height above ground (l)
Δh	-- plume rise (l)
ΔT	-- temperature difference between ambient air and stack gas (τ)
$(\Delta T)_c$	-- temperature difference for crossover from momentum to buoyancy-dominated plume (τ)
$\partial\theta/\partial z$	-- vertical potential temperature gradient of a layer of air (τ/l)
π	-- pi, 3.14159
e	-- base of natural logarithms, 2.71828
σ_y	-- lateral dispersion parameter (l)
σ_{ye}	-- effective lateral dispersion (l)
σ_{yo}	-- buoyancy-induced lateral dispersion (l)
σ_z	-- vertical dispersion parameter (l)
σ_{ze}	-- effective vertical dispersion (l)
σ_{zo}	-- buoyancy-induced vertical dispersion (l)
χ_p	-- concentration due to a point source (m/l^3)

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SECTION 1

INTRODUCTION

PTPLU (from PoinT PLUme) provides a method for estimating maximum ground-level concentrations from a single point source. The algorithm is based on Gaussian plume modeling assumptions incorporating the Pasquill-Gifford (P-G) dispersion parameters. Briggs' plume rise equations (Briggs, 1969) are employed by the model to determine the effective height of pollutant release.

Three technical options are available with PTPLU. Stack downwash may be considered, as well as buoyancy-induced dispersion and gradual plume rise. In addition, anemometer height, wind-profile exponents, and mixing height can be specified on input.

The routines employed to estimate dispersion by PTPLU have been extracted from MPTER (Multiple Point source algorithm with TERrain adjustments) (Pierce and Turner, 1980), which is in turn based on point-source segments of the rural version of RAM (Turner and Novak, 1978). PTPLU provides an economical and technically sound approach to estimating maximum concentrations for comparison with ambient air quality standards and for use in air pollution research.

Modeling the effects of the release of inert pollutants into the atmosphere usually follows a three-step procedure. First, simple screening steps are performed using a hand calculator or air quality nomograms. This simple screening method is, as a rule, sufficiently conservative to ensure that maximum concentrations will not be underestimated. If results of the simple screening indicate a potential air quality problem, a more detailed screening is warranted. This intermediate step usually involves the use of simple computer models to quantify the effects of pollutant release on air quality. A more elaborate procedure is followed when detailed screening indicates that a more refined analysis is required. For sources with significant potential effects, computation continues, using models better suited for handling multiple sources, multiple receptors, and topographic effects. The user is referred to the "Guideline on Air Quality Models" (U. S. Environmental Protection Agency, 1978) in selecting the models appropriate for regulatory applications.

The model described herein is suited for the intermediate step of detailed screening. If concentrations are low, no detailed modeling will then be required. In this manner, resources are conserved, and only potentially troublesome sources are left for analysis with the more refined models.

The Environmental Operations Branch of EPA supports the User's Network for Applied Modeling of Air Pollution--a set of models commonly known by the acronym UNAMAP. A brief description of the latest version of UNAMAP is available from the Environmental Operations Branch.

SECTION 2

DATA-REQUIREMENTS CHECKLIST

PTPLU requires data on options, sources, meteorology, and receptors. The user must indicate whether any of three options--gradual rise, stack downwash, or buoyancy-induced dispersion--is to be employed. Information required on the sources includes the following:

- source strength (grams per second),
- physical stack height (meters),
- stack gas temperature (kelvin),
- stack gas velocity (meters per second), and
- stack inside diameter (meters).

The meteorological data needed to compute maximum concentrations are as follows:

- ambient air temperature (kelvin),
- mixing height (meters),
- wind-profile exponents, and
- anemometer height (meters).

The only input required for receptors is the uniform height above ground of the receptors (in meters).

Because the maximum concentration is directly proportional to the emission rate of the source, care should be exercised to accurately determine this parameter. The mixing height and ambient air temperature should be representative of the vicinity of the source.

SECTION 3

FEATURES AND LIMITATIONS

As noted previously, PTPLU is an upgraded version of program PTMAX released in mid-1973 (UNAMAP Version 1). Since then, several larger models have been developed, such as CRSTER (U. S. Environmental Protection Agency, 1977), RAM, and MPTER. Certain features of these more complex models suitable for detailed screening have been transferred to PTPLU. Hence, a number of features not found in PTMAX are now available in PTPLU. These improvements are as follows:

- calculations using wind speeds at anemometer height and wind speeds extrapolated to stack top;
- optional gradual plume rise;
- optional stack downwash;
- optional buoyancy-induced dispersion;
- three modes of operation: batch, interactive with a paper terminal, and interactive with a video display;
- input of anemometer height;
- input of mixing height;
- input of wind-profile exponents;
- calculations for any number of single sources in one run; and
- consideration of momentum-dominated as well as buoyancy-dominated plumes.

PTPLU still retains some of the limitations of PTMAX, however. Among these are the following:

- predetermined wind speeds,
- unsuitability for complex terrain,
- no consideration of building downwash,

- no provision for calculating the effect of multiple point sources,
- no consideration of fumigation, and
- no consideration of pollutant removal or chemical reactions.

The model is most applicable within 10 km of the source. Beyond this distance, the estimates are expected to be less accurate, due to mesoscale influences such as wind direction shear with height and changing meteorological conditions during the time of transport.

As a screening model, PTPLU can be applied to single sources for the following:

- monitoring-network design,
- prevention of significant deterioration,
- new source review,
- fuel-conversion studies,
- control technology evaluation, and
- combustion-source permit applications.

PTPLU is primarily useful in determining the maximum one-hour concentration from a point source and the meteorological conditions associated with the maximum. Maximum concentrations are computed for 49 different combinations of wind speed and stability.

PTPLU can also be used in selecting the distances used as input into the models CRSTER and MPTER for generation of polar coordinate receptor arrays.

SECTION 4

TECHNICAL DESCRIPTION

PTPLU is a Gaussian plume dispersion model designed to screen maximum concentrations from single point sources. Persons not familiar with Gaussian point source modeling techniques and plume rise estimates are referred to Appendix A.

PTPLU determines the distance to and the magnitude of maximum concentrations from a point source for 49 internally generated combinations of wind speed and stability. PTPLU is based on the following modeling assumptions:

- the wind speed existing at stack top applies to both plume rise and dilution;
- plume rise is calculated using methods suggested by Briggs;
- the pollutant release is continuous at a rate specified by the user;
- calculations are made as if the atmosphere has reached a steady-state condition; and
- for unstable and neutral conditions, complete eddy reflection is calculated both from the ground and from the stable layer aloft given by the mixing height.

In calculating maximum concentrations, PTPLU is much like the PTMAX algorithm (Turner and Busse, 1973). However, PTPLU calculates concentrations for both wind speeds constant with height and wind speeds extrapolated to stack top. In addition to the user-supplied wind-profile exponents, PTPLU allows for optional calculations due to the effect of 1) gradual plume rise, 2) stack downwash, and 3) buoyancy-induced dispersion. Any one of these processes can alter the distance or magnitude of maximum concentration. Thus, the user is offered more flexibility in screening analyses.

The distance to maximum concentration is determined by an iterative sequential search. For each combination of wind speed and stability, the maximum concentration is selected from 16 fixed distances (0.1, 0.3, 0.5, 0.7, 1, 2, 3, 5, 7, 10, 15, 20,

30, 40, 50, and 100 km). This distance then becomes the start for the iterative search for the maximum. Calculations begin with increments appropriate to the starting point (+0.1 km for starting points 0.1-0.7 km, +1 km for starting points 1-7 km, +10 km for starting points 10-50 km, and -10 km for the 100-km starting point). Iterations proceed back and forth in one-tenth increments until the increment reaches one meter. If the distance of the maximum exceeds 100 km, the search ceases and a warning message is printed.

Figure 1 illustrates the technique used to find the maximum concentration and the distance to the maximum. In the initial step, a concentration is calculated sequentially at each of the 16 fixed distances noted above, and an absolute maximum is selected from the 16 values. The chosen maximum is represented by point 1 in Figure 1. The iterative search begins here, moving from right to left in fixed increments along the curve. Concentrations are computed using this increment until a lower concentration is encountered. At this point the direction is reversed and this point becomes the starting point for the next iteration, with a new distance increment reduced by an order of magnitude from the previous one. As indicated in Figure 1, the next two iterations yield starting points at points 3 and 4. The search for the absolute maximum ceases when the increment has been reduced to one meter.

Gradual plume rise (option 1) is available as an optional calculation in PTPLU. Although the 2/3 dependence for rising plumes determines average plume height with distance quite well, the dispersive processes that occur during buoyant rise are thought to be different from those that occur during steady-state transport. The P-G dispersion parameters represent horizontal and vertical dispersion about a horizontal plume, which may or may not be appropriate for estimating dispersion about a bent-over plume. By making computations with and without gradual plume rise, identification of potentially high concentrations is possible. When gradual rise is not employed, computations use only the final effective plume height.

Stack-top downwash (option 2) can be considered using the methods of Briggs. In such an analysis, a height increment is deducted from the physical height before momentum or buoyancy rise is determined. Use of this option primarily affects computations from stacks having small ratios of exit velocity to wind speed.

Buoyancy-induced dispersion calculations (option 3) are offered because emitted plumes undergo a certain amount of growth during the plume rise phase. This is due to the turbulent motions associated with conditions of plume release and the turbulent entrainment of ambient air. During the initial growth phases of release, the plume is assumed to be nearly symmetrical

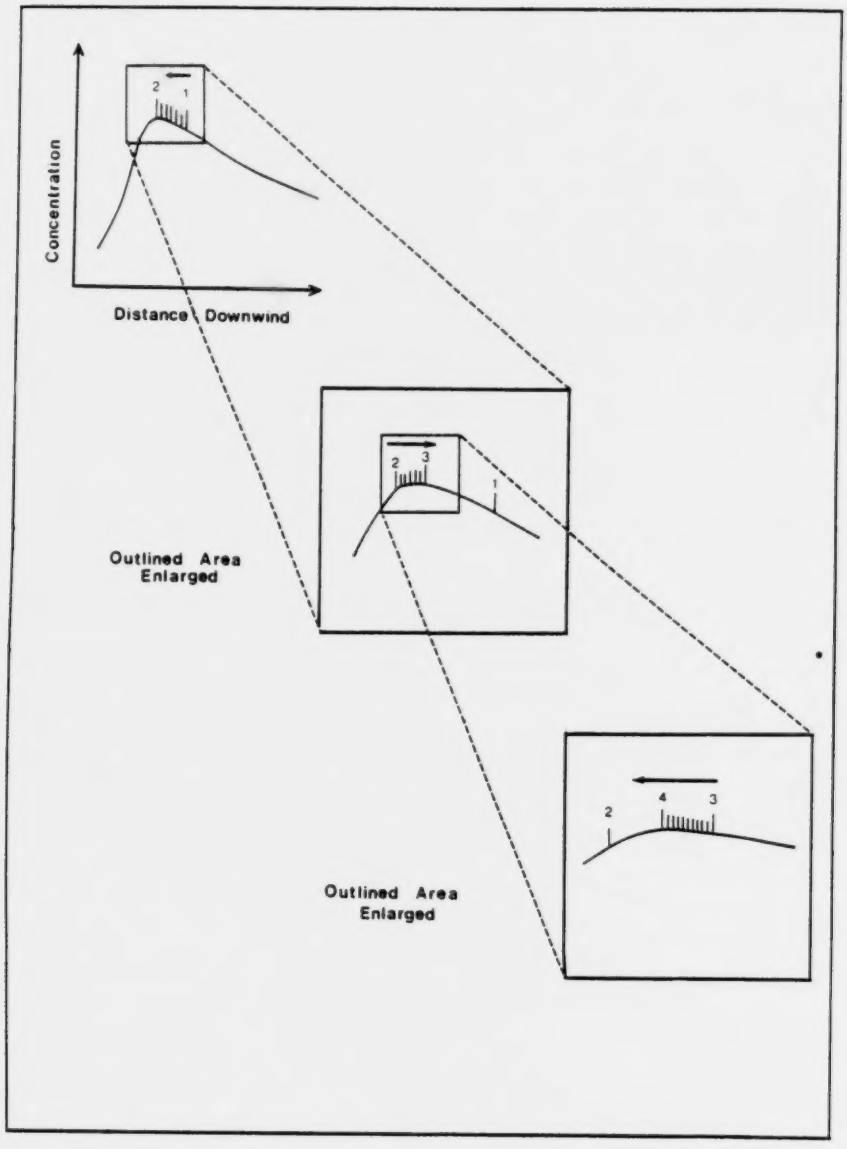

Figure 1. Iterative search routine used by PTPLU.

about its centerline; hence, the buoyancy-induced dispersion in the horizontal direction is modeled as equal to that in the vertical direction. The contribution by buoyant plume rise to the total dispersion is small compared with the dispersion caused by atmospheric turbulence. The maximum effects on ground-level concentrations occur for short heights of release combined with large plume rise, but, in general, buoyancy-induced dispersion has little effect on maximum surface concentrations from elevated releases.

To simulate increased wind speed with height, PTPLU requires the input of wind-profile exponents for each stability class. With this feature, maximum concentrations are computed for both wind speed at anemometer height and wind speed extrapolated to stack top.

The three options and the additional calculations for extrapolated wind speeds allow more flexibility and realism in identifying maximum concentrations. When employing PTPLU as a screening model for regulatory applications, the user is advised to contact the regional meteorologist or modeling contact about the proper specifications of options and wind-profile exponents.

SECTION 5

PROGRAM OVERVIEW AND STRUCTURE

PTPLU may be run either in batch mode or interactively. There are two interactive versions: one with minimal output, quite useful for terminals using paper, and one with expanded output useful for terminals with video display.

The interactive version consists of the batch version (modified to serve as a subroutine) and a set of subroutines for preparing the input to the model. The program is menu-driven so that the user may select for execution any one of a number of routines. Routines are available for entering or modifying (any number of times) meteorology, receptor height, options, source parameters, and run title. The user may also invoke a subroutine to display the current input data. After the data have been prepared in this interactive manner, the model may be executed. When each subroutine has finished execution, the user is presented with the original menu. The interactive session is completed by selecting "END" on the menu.

There are two versions of the interactive routines within the program, and the first action of the user is to select which version is to be used. One version produces unabridged output with full headings and data descriptions. The other produces abridged output with little data description. The unabridged version is designed for use with a visual-display output device. In such an output medium, length of output has little effect on running time or cost. The abridged version is designed for use with a hard-copy device, in which case length of output affects both running time and cost. In addition, the output of the unabridged version assists a new user by means of full data descriptions, whereas the abridged version is more useful to an experienced user who is familiar with the operation of the program and can work with abbreviated output.

The program contains default data, which serve as both a template for the user and a built-in test data set. The default data represent a hypothetical source of medium height. The default source parameters are as follows: source strength of 2750 g/s, physical stack height of 165 m, exit temperature of 425 K, exit velocity of 38 m/s, and inside stack diameter of 4.5 m. The remaining default data were selected as being typical. All options default to 1 (use option). Ambient air temperature

and mixing height default to 293 K and 2000 m, respectively. Anemometer height is taken as 10 m. Wind-profile exponents default to 0.07, 0.07, 0.10, 0.15, 0.35, and 0.55 for stability classes A through F, respectively. These values correspond to a roughness parameter of 0.03 m. The height of the receptor defaults to zero (ground level).

When the interactive routines are expecting numeric input from the user, care must be taken that data of the proper type are entered. The entry of alphabetic characters when numeric data are expected can result in a FORTRAN error and termination of the program. If this arrangement is not satisfactory, it may be possible to add a routine that reads numeric data as alphanumeric data, checks the format of the input, and either converts the alphanumeric data to a number or produces an error message under program control. Alternatively, on many systems, the ERR= option of the FORTRAN language could be used to process this error (the notable exception being IBM OS systems).

The subroutines of the model (PH, TPMX, PHX, RCON, and PSIG) are identical in the batch and interactive versions. The main routine of the batch version has been transformed into subroutine PTPLU of the interactive version. The conversion involved replacing read statements with subroutine parameters and assignment statements. Also, the format of the output was modified for use with a 79-character visual display. Aside from these changes of input and output, subroutine PTPLU is identical to the main routine of the batch version.

PROGRAM MODULES

IPTPLU -- Main module of the interactive version. IPTPLU invokes either LPTPLU or SPTPLU depending on the type of output desired--long form for CRT runs, short form for hard-copy terminals.

IPLDIS -- Prints model input parameters as currently available in memory.

IPLMET -- Allows substitution of meteorological parameters.

IPLOPT -- Allows changing of options.

IPLREC -- Allows changing of receptor height.

IPLSOR -- Allows modification of source parameters.

IPLTTL -- Provides a way to change the title.

LPTPLU -- Unabridged interactive version of PTPLU. Provides a menu-driven means to prepare input and execute the model.

PH -- Calculates specific plume rise parameters for a given wind speed.

PHX -- Calculates gradual plume rise, if the option is employed.

PSIG -- Calculates the lateral and vertical dispersion parameters as a function of distance from the source and stability class.

PTPLU -- Main module of the batch version and a subroutine of the interactive version. PTPLU produces all printed output (input parameters, calculated parameters, and output tables), calculates the plume rise as a function of wind speed, and controls the input to TPMX in order to produce the maximum concentration tables.

RCON -- Calculates the relative concentration (concentration divided by source strength) under a given set of conditions (solves the appropriate Gaussian equation).

SPLDIS -- Abridged display of interactive input data.

SPLMET -- Abridged modification of interactive meteorological data.

SPLOPT -- Abridged modification of interactive options.

SPLREC -- Abridged modification of receptor height.

SPLSOR -- Abridged modification of source data.

SPLTTL -- Abridged modification of run title.

SPTPLU -- Abridged interactive version of PTPLU. Provides a terse menu-driven means to prepare input and execute the model.

TPMX -- Searches for the distance to the maximum concentration by calling RCON, first at a set of fixed distances and then at incremental distances.

Figure 2 shows the structure of the batch version of PTPLU.

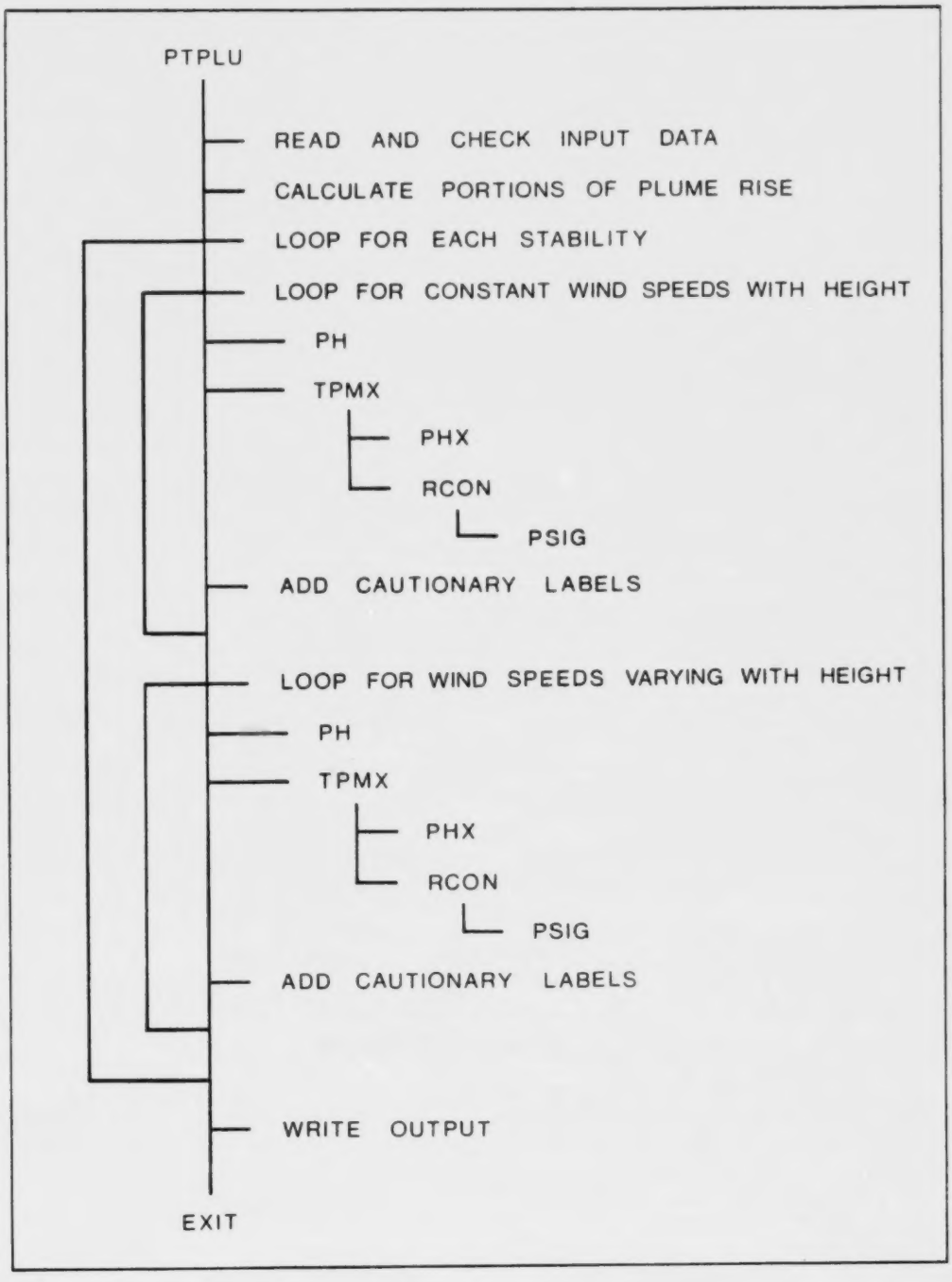

Figure 2. Structure of batch version of PTPLU.

SECTION 6

INPUT DATA PREPARATION

Table 1 (below) applies to input preparation for the batch execution mode. Data requirements are identical to those of the interactive mode. Data fields follow a free form (i.e., they are separated by commas). The input data should conform to the variable-name type. That is, decimals should be included for all values corresponding to real variables.

TABLE 1. RECORD INPUT SEQUENCE*

Record type	Variable name	Variable description
1	IOPT(1)	Gradual plume rise option
	IOPT(2)	Stack downwash option
	IOPT(3)	Buoyancy-induced dispersion option (1 = use option, 0 = do not use option)
	T	Ambient air temperature (kelvin) (default value is 293 K)
	HL	Mixing height (meters)
	Z	Receptor's elevation above ground (meters)
2	HANE	Anemometer height (meters)
	PL	Wind-profile exponents (6 values)
3	ALP	80-character title
4	Q	Source strength (grams per second)
	HP	Physical stack height (meters)
	TS	Stack gas temperature (kelvin)
	VS	Stack gas velocity (meters per second)
	D	Stack diameter (meters)

* Record Types 3 and 4 may be repeated (as a pair) any number of times.

When one of the interactive versions is used, the data are entered by the user in response to requests from the program. The same parameters are required for the batch and interactive versions.

SECTION 7

EXECUTION OF THE MODEL AND SAMPLE TEST

PTPLU produces an error-free compile on IBM MVS and Univac EXEC 8 computers. Execution results are comparable to within 0.2% for these two systems. The program can also be used in mini and microcomputers having comparable accuracy. A sample job stream for the batch version is presented below.

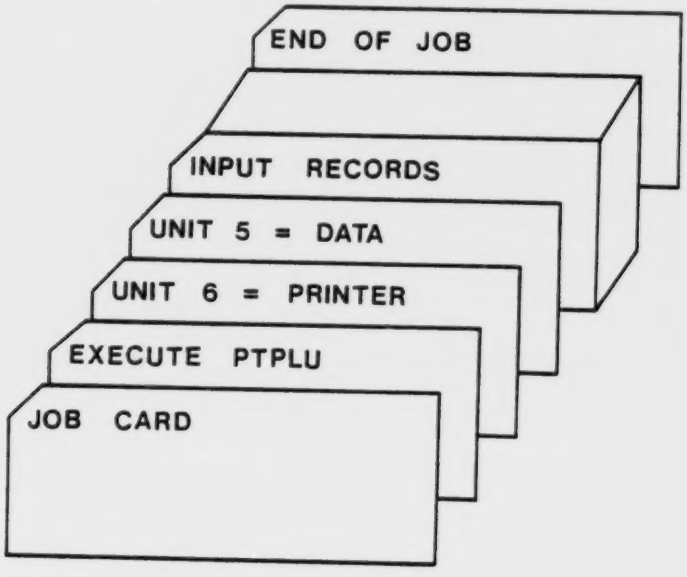

Figure 3. Sample job stream for batch version of PTPLU.

Test data for the batch version are as follows:

```
0,1,1,278.,1500.,2.
7.,.07,.07,.10,.15,.35,.55
PTPLU EXAMPLE RUN - INPUT BY T. PIERCE  12/29/80
1000.,200.,450.,20.,5.
```

A job stream for a Univac EXEC 8 system might have the following form:

```
@RUN,R/R JOB-ID,ETC
@ASG,A MODELS*LOAD.
@XQT MODELS*LOAD.PTPLU
(input records shown above)
@FIN
```

The following is a sample job stream for an IBM system under OS or MVS:

```
//JOBID    JOB  (PROJ,ACCT,OTHER),CLASS=A,TIME=1
//XPTPLU   EXEC PGM=PTPLU,TIME=(,05)
//STEPLIB  DD   DSN=USER.MODELS.LOAD,DISP=SHR
//FT06F001 DD   SYSOUT=A
//FT05F001 DD   *
(input records shown above)
/*
//
```

A sample job stream for a CDC system under Scope 3.14 may look as follows:

```
XX,T05,P4.
USER,HALE,EPA.
PROJECT,*PRJ*XX.
ATTACH,LIB,MODELSLIB,ID=XX.
LIBRARY,LIB.
PTPLU.
*
(input records shown above)
*
```

A schematic illustrating the various sections of the two-page output resulting from the batch version is shown in Figure 4. Model outputs include a heading (A in Figure 4) that indicates the program name and source. Section B displays the input parameters. Section C gives two calculated values, volumetric flow and the buoyancy flux parameter used for plume rise. Section D contains the output, with results for the assumption of constant wind speed with height on the left and those for extrapolated wind speed with height on the right. For each combination of wind speed and stability, the maximum concentration, the distance of the maximum, and the plume

effective height at this distance are given. Section E contains qualifying footnotes that may be referred to in section D. Figure 5 gives the batch run output of the sample test.

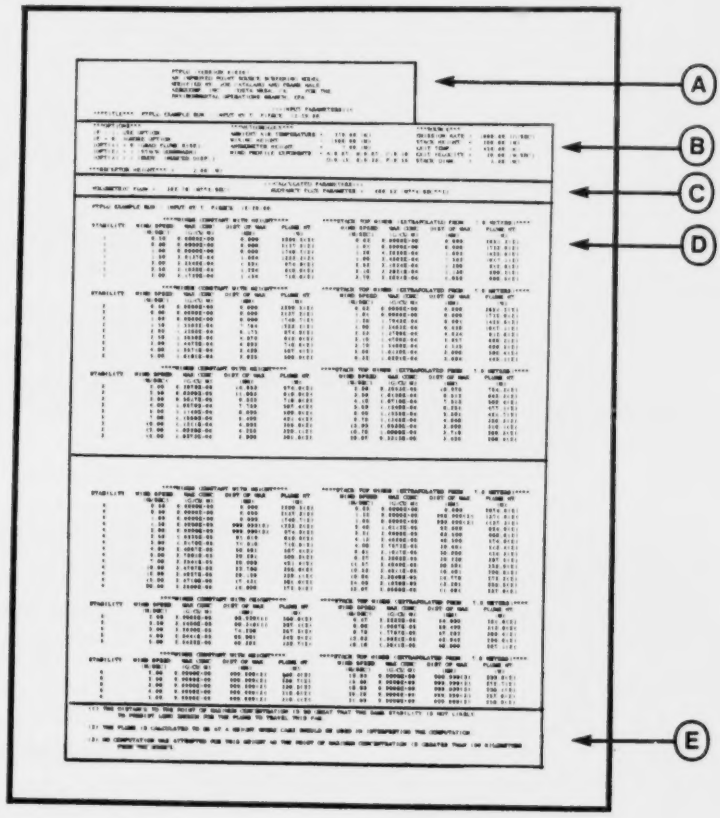

Figure 4. Schematic of batch output of PTPLU.

In the interactive version, a sample test is built into the program. The only step involved in running the sample test is selecting "RUN" from the main menu. The output resulting from the unabridged interactive version using this built-in test data set is given in Figure 6, where, as illustration, all interactive options are exercised. Users may verify the proper execution of the program by comparing their results with those given in Figure 6.

PTPLU (VERSION 81036)
AN IMPROVED POINT SOURCE SCREENING MODEL
MODIFIED BY: JOE CATALANO AND FRANK HALE
AEROCOMP, INC. - COSTA MESA, CA FOR THE
ENVIRONMENTAL OPERATIONS BRANCH, EPA

>>>INPUT PARAMETERS<<<

TITLE PTPLU EXAMPLE RUN - INPUT BY T. PIERCE 12/29/80

OPTIONS
IF - 1, USE OPTION
IF - 0, IGNORE OPTION
IOPT(1) - 0 (GRAD PLUME RISE)
IOPT(2) - 1 (STACK DOWNWASH)
IOPT(3) - 1 (BUOY. INDUCED DISP.)

METEOROLOGY
AMBIENT AIR TEMPERATURE = 278.00 (K)
MIXING HEIGHT = 1500.00 (M)
ANEMOMETER HEIGHT = 7.00 (M)
WIND PROFILE EXPONENTS = A:0.07, B:0.07, C:0.10 D:0.15, E:0.35, F:0.55

SOURCE
EMISSION RATE = 1000.00 (G/SEC)
STACK HEIGHT = 200.00 (M)
EXIT TEMP. = 450.00 (K)
EXIT VELOCITY = 20.00 (M/SEC)
STACK DIAM. = 5.00 (M)

RECEPTOR HEIGHT - 2.00 (M)

>>>CALCULATED PARAMETERS<<<

VOLUMETRIC FLOW = 392.70 (M**3/SEC)
BUOYANCY FLUX PARAMETER = 468.52 (M**4/SEC**3)

PTPLU EXAMPLE RUN - INPUT BY T. PIERCE 12/29/80

****WINDS CONSTANT WITH HEIGHT****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
1	0.50	0.0000E+00	0.000	3299.5(2)
1	0.80	0.0000E+00	0.000	2137.2(2)
1	1.00	0.0000E+00	0.000	1749.7(2)
1	1.50	3.9137E-04	1.664	1233.2(2)
1	2.00	3.3549E-04	1.551	974.9(2)
1	2.50	3.1038E-04	1.296	819.9(2)
1	3.00	3.1729E-04	1.156	716.6(2)

****STACK TOP WINDS (EXTRAPOLATED FROM 7.0 METERS)****

WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
0.63	0.0000E+00	0.000	2651.2(2)
1.01	0.0000E+00	0.000	1732.0(2)
1.26	4.2626E-04	1.693	1425.6(2)
1.90	3.4502E-04	1.582	1017.1(2)
2.53	3.1034E-04	1.280	812.8(2)
3.16	3.2021E-04	1.130	690.2(2)
3.79	3.2851E-04	1.059	608.5(2)

****WINDS CONSTANT WITH HEIGHT****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
2	0.50	0.0000E+00	0.000	3299.5(2)
2	0.80	0.0000E+00	0.000	2137.2(2)
2	1.00	0.0000E+00	0.000	1749.7(2)
2	1.50	1.5562E-04	7.764	1233.2(2)
2	2.00	1.3268E-04	6.175	974.9(2)
2	2.50	1.3650E-04	4.679	819.9(2)
2	3.00	1.4472E-04	4.092	716.6(2)
2	4.00	1.5571E-04	3.428	587.4(2)
2	5.00	1.6101E-04	3.025	509.9(2)

****STACK TOP WINDS (EXTRAPOLATED FROM 7.0 METERS)****

WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
0.63	0.0000E+00	0.000	2651.2(2)
1.01	0.0000E+00	0.000	1732.0(2)
1.26	1.7943E-04	8.001	1425.6(2)
1.90	1.3483E-04	6.628	1017.1(2)
2.53	1.3700E-04	4.634	812.8(2)
3.16	1.4700E-04	3.957	690.2(2)
3.79	1.5400E-04	3.535	608.5(2)
5.06	1.6120E-04	3.006	506.4(2)
6.32	1.6291E-04	2.684	445.1(2)

****WINDS CONSTANT WITH HEIGHT****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
3	2.00	8.2078E-05	14.653	974.9(2)
3	2.50	8.8390E-05	11.063	819.9(2)
3	3.00	9.5617E-05	9.533	716.6(2)
3	4.00	1.0570E-04	7.759	587.4(2)
3	5.00	1.1146E-04	6.696	509.9(2)
3	7.00	1.1556E-04	5.499	421.4(2)
3	10.00	1.1311E-04	4.602	355.0(2)
3	12.00	1.0928E-04	4.255	329.1(2)
3	15.00	1.0373E-04	3.886	301.6(2)

****STACK TOP WINDS (EXTRAPOLATED FROM 7.0 METERS)****

WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
2.80	9.2853E-05	10.070	754.2(2)
3.50	1.0128E-04	8.512	643.3(2)
4.19	1.0710E-04	7.513	569.4(2)
5.59	1.1349E-04	6.251	477.1(2)
6.99	1.1555E-04	5.501	421.7(2)
9.79	1.1345E-04	4.648	358.3(2)
13.98	1.0538E-04	3.999	310.1(2)
16.78	1.0068E-04	3.716	289.3(2)
20.97	9.3312E-05	3.435	268.4(2)

Figure 5. Batch output of PTPLU.

STABILITY	****WINDS CONSTANT WITH HEIGHT**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)	****STACK TOP WINDS (EXTRAPOLATED FROM 7.0 METERS)**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
4	0.50	0.0000E+00	0.000	3299.5(2)	0.83	0.0000E+00	0.000	2074.6(2)
4	0.80	0.0000E+00	0.000	2137.2(2)	1.32	9.9990E+09	999.999(3)	1371.6(2)
4	1.00	0.0000E+00	0.000	1749.7(2)	1.65	9.9990E+09	999.999(3)	1137.3(2)
4	1.50	9.9990E+09	999.999(3)	1233.2(2)	2.48	1.6112E-05	92.600	824.9(2)
4	2.00	9.9990E+09	999.999(3)	974.9(2)	3.31	2.0808E-05	63.590	668.6(2)
4	2.50	1.6235E-05	91.619	819.9(2)	4.13	2.4628E 05	48.590	574.9(2)
4	3.00	1.9170E-05	71.819	716.6(2)	4.96	2.7673E-05	39.601	512.4(2)
4	4.00	2.4067E-05	50.581	587.4(2)	6.61	3.1917E-05	30.000	434.3(2)
4	5.00	2.7801E-05	39.291	509.9(2)	8.27	3.3882E-05	26.220	387.5(2)
4	7.00	3.2541E-05	29.980	421.4(2)	11.57	3.4949E-05	20.591	333.9(2)
4	10.00	3.4767E-05	22.760	355.0(2)	16.53	3.4511E-05	16.401	290.8(2)
4	12.00	3.4927E-05	20.120	329.1(2)	19.84	3.3640E-05	14.770	273.2(2)
4	15.00	3.4718E-05	17.431	301.6(2)	24.80	3.1826E-05	13.201	255.5(2)
4	20.00	3.3589E-05	14.690	272.5(2)	33.07	2.8586E-05	11.691	237.9(2)

STABILITY	****WINDS CONSTANT WITH HEIGHT**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)	****STACK TOP WINDS (EXTRAPOLATED FROM 7.0 METERS)**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
5	2.00	3.9085E-05	88.920(1)	380.0(2)	6.47	2.2232E-05	54.680	321.8(2)
5	2.50	3.5456E-05	80.316(1)	367.1(2)	8.08	1.9687E-05	50.490	313.0(2)
5	3.00	3.2630E-05	74.220	357.3(2)	9.70	1.7767E-05	47.282	306.4(2)
5	4.00	2.8441E-05	65.981	342.9(2)	12.93	1.5021E-05	42.942	296.6(2)
5	5.00	2.5432E-05	60.382	332.7(2)	16.16	1.3611E-05	40.000	287.1(2)

STABILITY	****WINDS CONSTANT WITH HEIGHT**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)	****STACK TOP WINDS (EXTRAPOLATED FROM 7.0 METERS)**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
6	2.00	9.9990E+09	999.999(3)	349.4(2)	12.64	9.9990E+09	999.999(3)	280.8(2)
6	2.50	9.9990E+09	999.999(3)	338.7(2)	15.80	9.9990E+09	999.999(3)	272.7(2)
6	3.00	9.9990E+09	999.999(3)	330.5(2)	18.96	9.9990E+09	999.999(3)	266.1(2)
6	4.00	9.9990E+09	999.999(3)	318.6(2)	25.28	9.9990E+09	999.999(3)	257.0(2)
6	5.00	9.9990E+09	999.999(3)	310.1(2)	31.60	9.9990E+09	999.999(3)	250.9(2)

(1) THE DISTANCE TO THE POINT OF MAXIMUM CONCENTRATION IS SO GREAT THAT THE SAME STABILITY IS NOT LIKELY TO PERSIST LONG ENOUGH FOR THE PLUME TO TRAVEL THIS FAR.

(2) THE PLUME IS CALCULATED TO BE AT A HEIGHT WHERE CARE SHOULD BE USED IN INTERPRETING THE COMPUTATION.

(3) NO COMPUTATION WAS ATTEMPTED FOR THIS HEIGHT AS THE POINT OF MAXIMUM CONCENTRATION IS GREATER THAN 100 KILOMETERS FROM THE SOURCE.

Figure 5. (continued)

```
 DO YOU WISH TO USE THE ABRIDGED VERSION?
NO

          IPTPLU - IMPROVED POINT SOURCE SCREENING MODEL - VERSION 81035
          THE INTERACTIVE VERSION OF PTPLU DEVELOPED UNDER CONTRACT BY
          AEROCOMP, INC. - COSTA MESA, CA      FOR THE
          ENVIRONMENTAL OPERATIONS BRANCH, EPA

  1 CHANGE OPTIONS
  2 CHANGE METEOROLOGY
  3 CHANGE RECEPTOR ELEVATION
  4 CHANGE SOURCE CHARACTERISTICS
  5 CHANGE TITLE
  6 DISPLAY INPUT DATA
  7 RUN
  8 END

 ENTER SELECTION (1,2,3,4,5,6,7 OR 8)
1

 PRESENT OPTIONS ARE:
  1  COMPUTE GRADUAL RISE
  2  COMPUTE DOWNWASH
  3  COMPUTE BUOYANCY INDUCED DISPERSION

 CHANGE WHICH OPTION? (4 TO DISPLAY; 5 TO RETURN TO MENU)
5

  1 CHANGE OPTIONS
  2 CHANGE METEOROLOGY
  3 CHANGE RECEPTOR ELEVATION
  4 CHANGE SOURCE CHARACTERISTICS
  5 CHANGE TITLE
  6 DISPLAY INPUT DATA
  7 RUN
  8 END

 ENTER SELECTION (1,2,3,4,5,6,7 OR 8)
2

 PRESENT METEOROLOGY:
   1  AMBIENT AIR TEMPERATURE (K): 293.0
   2  MIXING HEIGHT (M):  2000.0
   3  ANEMOMETER HEIGHT (M):  10.0
   4  WIND PROFILE EXPONENTS:
       0.07 0.07 0.10 0.15 0.35 0.55

 CHANGE WHICH ITEM? (5 TO DISPLAY; 6 TO RETURN TO MENU)
1
 ENTER NEW AIR TEMPERATURE (K):
293.0

 CHANGE WHICH ITEM? (5 TO DISPLAY; 6 TO RETURN TO MENU)
2
```

Figure 6. Output of unabridged interactive version of PTPLU.

```
 ENTER NEW MIXING HEIGHT (M):
2000.0

 CHANGE WHICH ITEM? (5 TO DISPLAY; 6 TO RETURN TO MENU)
3
 ENTER NEW ANEMOMETER HEIGHT (M):
10.0

 CHANGE WHICH ITEM? (5 TO DISPLAY; 6 TO RETURN TO MENU)
4
 ENTER NEW WIND PROFILE EXPONENTS (SIX):
 07,.07,.10,.15,.35,.55

 CHANGE WHICH ITEM? (5 TO DISPLAY; 6 TO RETURN TO MENU)
5

 PRESENT METEOROLOGY:
   1  AMBIENT AIR TEMPERATURE (K): 293.0
   2  MIXING HEIGHT (M):  2000.0
   3  ANEMOMETER HEIGHT (M):  10.0
   4  WIND PROFILE EXPONENTS:
      0.07 0.07 0.10 0.15 0.35 0.55

 CHANGE WHICH ITEM? (5 TO DISPLAY; 6 TO RETURN TO MENU)
6

  1 CHANGE OPTIONS
  2 CHANGE METEOROLOGY
  3 CHANGE RECEPTOR ELEVATION
  4 CHANGE SOURCE CHARACTERISTICS
  5 CHANGE TITLE
  6 DISPLAY INPUT DATA
  7 RUN
  8 END

 ENTER SELECTION (1,2,3,4,5,6,7 OR 8)
3

 PRESENT HEIGHT OF RECEPTORS IS (M):     0.0
 ENTER NEW RECEPTOR HEIGHT (M)
0.0

  1 CHANGE OPTIONS
  2 CHANGE METEOROLOGY
  3 CHANGE RECEPTOR ELEVATION
  4 CHANGE SOURCE CHARACTERISTICS
  5 CHANGE TITLE
  6 DISPLAY INPUT DATA
  7 RUN
  8 END

 ENTER SELECTION (1,2,3,4,5,6,7 OR 8)
4
```

Figure 6. (continued)

```
 PRESENT SOURCE CHARACTERISTICS ARE:
   1  SOURCE STRENGTH (G/SEC):  2750.0
   2  PHYSICAL HEIGHT OF STACK (M):  165.0
   3  STACK GAS TEMPERATURE (K): 425.0
   4  STACK GAS VELOCITY (M/SEC):  38.0
   5  INSIDE STACK DIAMETER (M):  4.5

 CHANGE WHICH CHARACTERISTIC? (6 TO DISPLAY; 7 TO RETURN)
1
 ENTER NEW SOURCE STRENGTH (G/SEC):
2750.0

 CHANGE WHICH CHARACTERISTIC? (6 TO DISPLAY; 7 TO RETURN)
2
 ENTER NEW PHYSICAL STACK HEIGHT (M):
165.0

 CHANGE WHICH CHARACTERISTIC? (6 TO DISPLAY; 7 TO RETURN)
3
 ENTER NEW STACK GAS TEMPERATURE (K):
425.0

 CHANGE WHICH CHARACTERISTIC? (6 TO DISPLAY; 7 TO RETURN)
4
 ENTER NEW STACK GAS VELOCITY (M/SEC):
38.0

 CHANGE WHICH CHARACTERISTIC? (6 TO DISPLAY; 7 TO RETURN)
5
 ENTER NEW INSIDE STACK DIAMETER (M):
4.50

 CHANGE WHICH CHARACTERISTIC? (6 TO DISPLAY; 7 TO RETURN)
6

 PRESENT SOURCE CHARACTERISTICS ARE:
   1  SOURCE STRENGTH (G/SEC):  2750.0
   2  PHYSICAL HEIGHT OF STACK (M):  165.0
   3  STACK GAS TEMPERATURE (K): 425.0
   4  STACK GAS VELOCITY (M/SEC):  38.0
   5  INSIDE STACK DIAMETER (M):  4.5

 CHANGE WHICH CHARACTERISTIC? (6 TO DISPLAY; 7 TO RETURN)
7

  1 CHANGE OPTIONS
  2 CHANGE METEOROLOGY
  3 CHANGE RECEPTOR ELEVATION
  4 CHANGE SOURCE CHARACTERISTICS
  5 CHANGE TITLE
  6 DISPLAY INPUT DATA
  7 RUN
  8 END
```

Figure 6. (continued)

```
 ENTER SELECTION (1,2,3,4,5,6,7 OR 8)
5

 PRESENT TITLE IS:
 *** TEST OF PTPLU ***
 CHANGE TO: (NOT MORE THAN 60 CHARACTERS)
DEMONSTRATION OF INTERACTIVE SESSION SUBMITTED BY T. CHICO

  1 CHANGE OPTIONS
  2 CHANGE METEOROLOGY
  3 CHANGE RECEPTOR ELEVATION
  4 CHANGE SOURCE CHARACTERISTICS
  5 CHANGE TITLE
  6 DISPLAY INPUT DATA
  7 RUN
  8 END

 ENTER SELECTION (1,2,3,4,5,6,7 OR 8)
6

 CURRENT INPUT DATA:

    OPTIONS:
       COMPUTE GRADUAL RISE
       COMPUTE DOWNWASH
       COMPUTE BUOYANCY INDUCED DISPERSION
    METEOROLOGY:
       AMBIENT AIR TEMPERATURE (K): 293.0
       MIXING HEIGHT (M):  2000.0
       ANEMOMETER HEIGHT (M):  10.0
       WIND PROFILE EXPONENTS:  0.07 0.07 0.10 0.15 0.35 0.55
    RECEPTOR HEIGHT (M):    0.0
    SOURCE CHARACTERISTICS:
       SOURCE STRENGTH (G/SEC):  2750.0
       PHYSICAL HEIGHT OF STACK (M):  165.0
       STACK GAS TEMPERATURE (K): 425.0
       STACK GAS VELOCITY (M/SEC):  38.0
       INSIDE STACK DIAMETER (M):  4.5
    TITLE:
       DEMONSTRATION OF INTERACTIVE SESSION SUBMITTED BY T. CHICO

 ENTER M TO RETURN TO MENU
M

  1 CHANGE OPTIONS
  2 CHANGE METEOROLOGY
  3 CHANGE RECEPTOR ELEVATION
  4 CHANGE SOURCE CHARACTERISTICS
  5 CHANGE TITLE
  6 DISPLAY INPUT DATA
  7 RUN
  8 END

 ENTER SELECTION (1,2,3,4,5,6,7 OR 8)
7
```

Figure 6. (continued)

```
PTPLU -- IMPROVED MODEL FOR SCREENING MAXIMUM CONCENTRATIONS -- VERSION 81035

***TITLE***
DEMONSTRATION OF INTERACTIVE SESSION SUBMITTED BY T. CHICO

***OPTIONS***
IF = 1, USE OPTION
IF = 0, IGNORE OPTION
IOPT(1) = 1  (GRAD PLUME RISE)
IOPT(2) = 1  (STACK DOWNWASH)
IOPT(3) = 1  (BUOY. INDUCED DISP.)

***METEOROLOGY***
AMBIENT AIR TEMPERATURE =   293.00 (K)
MIXING HEIGHT           =  2000.00 (M)
ANEMOMETER HEIGHT       =    10.00 (M)
WIND PROFILE EXPONENTS  = A:0.07, B:0.07, C:0.10
                          D:0.15, E:0.35, F:0.55

***RECEPTOR HEIGHT***   =     0.00 (M)

***SOURCE***
EMISSION RATE =  2750.00 (G/SEC)
STACK HEIGHT  =   165.00 (M)
EXIT TEMP.    =   425.00 (K)
EXIT VELOCITY =    38.00 (M/SEC)
STACK DIAM.   =     4.50 (M)

>>>CALCULATED PARAMETERS<<<

VOLUMETRIC FLOW =   604.36 (M**3/SEC)
BUOYANCY FLUX PARAMETER =   585.91 (M**4/SEC**3)


DEMONSTRATION OF INTERACTIVE SESSION SUBMITTED BY T. CHICO

****WINDS CONSTANT WITH HEIGHT****
STABILITY   WIND SPEED   MAX CONC    DIST OF MAX    PLUME HT
              (M/SEC)    (G/CU M)       (KM)          (M)
    1           0.50   0.0000E+00      0.000      2276.0(2)
    1           0.80   0.0000E+00      0.000      2380.3(2)
    1           1.00   8.5341E-04      1.971      1937.2(2)
    1           1.50   7.2139E-04      1.839      1346.5(2)
    1           2.00   8.1207E-04      1.152       900.2(2)
    1           2.50   9.7610E-04      1.042       715.1(2)
    1           3.00   1.0968E-03      0.967       601.1(2)

****STACK TOP WINDS (EXTRAPOLATED FROM  10.0 METERS)****
STABILITY   WIND SPEED   MAX CONC    DIST OF MAX    PLUME HT
              (M/SEC)    (G/CU M)       (KM)          (M)
    1           0.61   0.0000E+00      0.000      2365.5(2)
```

Figure 6. (continued)

1	0.97	8.6173E-04	1.974	1985.6(2)
1	1.22	7.9007E-04	1.931	1621.5(2)
1	1.83	7.4371E-04	1.205	995.2(2)
1	2.43	9.5698E-04	1.054	734.4(2)
1	3.04	1.1053E-03	0.962	593.6(2)
1	3.65	1.2024E-03	0.899	506.4(2)

****WINDS CONSTANT WITH HEIGHT****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
2	0.50	0.0000E+00	0.000	2276.0(2)
2	0.80	0.0000E+00	0.000	2380.3(2)
2	1.00	3.6782E-04	10.381	1937.2(2)
2	1.50	2.7921E-04	8.514	1346.5(2)
2	2.00	2.9739E-04	5.786	1051.1(2)
2	2.50	3.3243E-04	4.858	873.9(2)
2	3.00	3.6094E-04	4.264	755.7(2)
2	4.00	4.0207E-04	3.511	608.1(2)
2	5.00	4.2822E-04	3.053	519.4(2)

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
2	0.61	0.0000E+00	0.000	2365.5(2)
2	0.97	3.7696E-04	10.369	1985.6(2)
2	1.22	3.1362E-04	10.025	1621.5(2)
2	1.83	2.8484E-04	6.337	1136.0(2)
2	2.43	3.2815E-04	4.954	893.2(2)
2	3.04	3.6306E-04	4.222	747.6(2)
2	3.65	3.8972E-04	3.728	650.5(2)
2	4.87	4.2541E-04	3.103	529.1(2)
2	6.08	4.4524E-04	2.723	456.3(2)

****WINDS CONSTANT WITH HEIGHT****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
3	2.00	1.8735E-04	14.212	1051.1(2)
3	2.50	2.1485E-04	11.631	873.9(2)
3	3.00	2.3785E-04	9.980	755.7(2)
3	4.00	2.7289E-04	7.956	608.1(2)
3	5.00	2.9702E-04	6.750	519.4(2)
3	7.00	3.2415E-04	5.389	418.2(2)
3	10.00	3.3578E-04	4.380	342.2(2)
3	12.00	3.3386E-04	3.890	312.7(2)
3	15.00	3.2435E-04	3.599	283.1(2)

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
3	2.65	2.2207E-04	11.084	834.5(2)
3	3.31	2.5008E-04	9.217	700.6(2)
3	3.97	2.7203E-04	7.996	611.3(2)
3	5.29	3.0253E-04	6.483	499.7(2)
3	6.62	3.2060E-04	5.582	432.8(2)

Figure 6. (continued)

3	9.27	3.3497E-04	4.565	356.3(2)
3	13.24	3.3062E-04	3.806	298.9(2)
3	15.88	3.2074E-04	3.513	276.6(2)
3	19.85	3.0259E-04	3.218	254.3(2)

****WINDS CONSTANT WITH HEIGHT****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
4	0.50	0.0000E+00	0.000	2276.0(2)
4	0.80	0.0000E+00	0.000	2380.3(2)
4	1.00	9.9990E+09	999.999(3)	1937.2(2)
4	1.50	9.9990E+09	999.999(3)	1346.5(2)
4	2.00	9.9990E+09	999.999(3)	1051.1(2)
4	2.50	3.8419E-05	99.338	873.9(2)
4	3.00	4.6683E-05	76.209	755.7(2)
4	4.00	6.1618E-05	51.671	608.1(2)
4	5.00	7.4276E-05	38.990	519.4(2)
4	7.00	9.2719E-05	28.710	418.2(2)
4	10.00	1.0637E-04	20.774	342.2(2)
4	12.00	1.1080E-04	17.950	312.7(2)
4	15.00	1.1334E-04	15.293	283.1(2)
4	20.00	1.1179E-04	12.771	253.6(2)

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
4	0.76	0.0000E+00	0.000	2492.7(2)
4	1.22	9.9990E+09	999.999(3)	1619.8(2)
4	1.52	9.9990E+09	999.999(3)	1328.9(2)
4	2.28	9.9990E+09	999.999(3)	940.9(2)
4	3.05	4.7410E-05	74.688	746.9(2)
4	3.81	5.8910E-05	55.160	630.5(2)
4	4.57	6.9087E-05	43.631	553.0(2)
4	6.09	8.5636E-05	30.961	456.0(2)
4	7.61	9.6420E-05	26.493	397.8(2)
4	10.66	1.0815E-04	19.710	331.3(2)
4	15.23	1.1339E-04	15.131	281.4(2)
4	18.27	1.1285E-04	13.470	262.0(2)
4	22.84	1.0937E-04	11.871	242.6(2)
4	30.45	1.0377E-04	10.150	220.9(2)

****WINDS CONSTANT WITH HEIGHT****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
5	2.00	1.3457E-04	68.893(1)	362.4(2)
5	2.50	1.2444E-04	61.581	348.2(2)
5	3.00	1.1633E-04	56.252	337.4(2)
5	4.00	1.0392E-04	49.083	321.7(2)
5	5.00	9.4705E-05	44.291	310.4(2)

****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
5	5.34	9.2100E-05	42.981	307.3(2)

Figure 6. (continued)

```
    5            6.67      8.3409E-05      40.000          297.1(2)
    5            8.00      7.6437E-05      40.000          289.3(2)
    5           10.67      6.5760E-05      40.000          278.0(2)
    5           13.34      5.7935E-05      39.984          269.9(2)

****WINDS CONSTANT WITH HEIGHT****
STABILITY   WIND SPEED    MAX CONC      DIST OF MAX      PLUME HT
              (M/SEC)     (G/CU M)        (KM)             (M)
    6           2.00      9.9990E+09    999.999(3)       328.8(2)
    6           2.50      9.9990E+09    999.999(3)       317.1(2)
    6           3.00      9.9990E+09    999.999(3)       308.1(2)
    6           4.00      9.9990E+09    999.999(3)       295.0(2)
    6           5.00      9.9990E+09    999.999(3)       285.7(2)

****STACK TOP WINDS (EXTRAPOLATED FROM  10.0 METERS)****
STABILITY   WIND SPEED    MAX CONC      DIST OF MAX      PLUME HT
              (M/SEC)     (G/CU M)        (KM)             (M)
    6           9.35      9.9990E+09    999.999(3)       263.0(2)
    6          11.68      9.9990E+09    999.999(3)       256.0(2)
    6          14.02      9.9990E+09    999.999(3)       250.6(2)
    6          18.69      9.9990E+09    999.999(3)       242.8(2)
    6          23.37      9.9990E+09    999.999(3)       237.2(2)

(1) THE DISTANCE TO THE POINT OF MAXIMUM CONCENTRATION IS SO
    GREAT THAT THE SAME STABILITY IS NOT LIKELY TO PERSIST
    LONG ENOUGH FOR THE PLUME TO TRAVEL THIS FAR.

(2) THE PLUME IS CALCULATED TO BE AT A HEIGHT WHERE CARE
    SHOULD BE USED IN INTERPRETING THE COMPUTATION.

(3) NO COMPUTATION WAS ATTEMPTED FOR THIS HEIGHT AS THE POINT
    OF MAXIMUM CONCENTRATION IS GREATER THAN 100 KILOMETERS
    FROM THE SOURCE.


 1 CHANGE OPTIONS
 2 CHANGE METEOROLOGY
 3 CHANGE RECEPTOR ELEVATION
 4 CHANGE SOURCE CHARACTERISTICS
 5 CHANGE TITLE
 6 DISPLAY INPUT DATA
 7 RUN
 8 END

 ENTER SELECTION (1,2,3,4,5,6,7 OR 8)
8
 PTPLU RUN TERMINATED AT USER REQUEST
```

Figure 6. (continued)

Three cautionary messages are given by the program: one pertains to the probability that the stability will change before the plume can reach the estimated point of maximum concentration; one is for elevated plumes; and one pertains to maximum concentrations occurring at extreme distances. Effective heights of more than 200 m are regarded as extreme and are tagged with a cautionary message. Distances to maximum concentrations greater than 100 km are considered to be beyond the scope of this model. These calculations are tagged; the concentrations are shown as 9.9990E+09 g/m^3, and the distances are shown as 999.999 km.

To determine the probability that the stability will change before the plume can travel to the estimated point of maximum concentration, the distance to the maximum is divided by the wind speed (assuming a uniform wind speed at all points under consideration), yielding an estimated travel time. If this travel time is greater than the threshold value for the stability considered, the corresponding distance is tagged. Travel-time threshold values employed by the program are as follows:

Stability	Travel time
A	4.0 hours
B	6.0 hours
C	8.0 hours
D	277.5 hours
E	8.0 hours
F	8.0 hours

SECTION 8

EXAMPLE CALCULATION

The following example illustrates the application of PTPLU. A 40-meter stack emits 151 g/s of a pollutant. The stack diameter is 2.68 m, the exit velocity is 20.0 m/s, and the stack gas temperature is 350 K. It is desired to determine the maximum concentration, to find the distance at which it occurs, and to see, in general, how concentration varies with wind speed and stability. For the options, ambient temperature, mixing height, receptor elevation, anemometer height, and wind speed power-law exponents, users are referred to the batch output of Figure 7.

The maximum concentration is selected as the largest concentration in column 7 of output section D (see Figure 4 for designation of output sections). The concentrations in this column can also be plotted as a function of wind speed, to give an overall picture of the dependency of pollutant concentrations on wind speed and stability.

Portions of this example are used in the sensitivity analysis presented in Appendix C.

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PTPLU (VERSION 81036)
 AN IMPROVED POINT SOURCE SCREENING MODEL
 MODIFIED BY: JOE CATALANO AND FRANK HALE
 AEROCOMP, INC. - COSTA MESA, CA     FOR THE
 ENVIRONMENTAL OPERATIONS BRANCH, EPA

                                >>>INPUT PARAMETERS<<<
***TITLE***  EXAMPLE CALCULATION - SECTION 8 OF USER'S GUIDE

***OPTIONS***                    ***METEOROLOGY***                          ***SOURCE***
IF - 1, USE OPTION               AMBIENT AIR TEMPERATURE =   293.00 (K)      EMISSION RATE =   151.00 (G/SEC)
IF - 0, IGNORE OPTION            MIXING HEIGHT           =  1500.00 (M)     STACK HEIGHT  =    40.00 (M)
IOPT(1) - 1 (GRAD PLUME RISE)    ANEMOMETER HEIGHT       =    10.00 (M)     EXIT TEMP.    =   350.00 (K)
IOPT(2) - 0 (STACK DOWNWASH)     WIND PROFILE EXPONENTS  = A:0.07, B:0.07, C:0.10  EXIT VELOCITY =  20.00 (M/SEC)
IOPT(3) - 0 (BUOY. INDUCED DISP.)                          D:0.15, E:0.35, F:0.55  STACK DIAM.  =   2.68 (M)

***RECEPTOR HEIGHT*** -      0.00 (M)

                                >>>CALCULATED PARAMETERS<<<
VOLUMETRIC FLOW =    112.82 (M**3/SEC)          BUOYANCY FLUX PARAMETER =    57.35 (M**4/SEC**3)

EXAMPLE CALCULATION - SECTION 8 OF USER'S GUIDE

                    ****WINDS CONSTANT WITH HEIGHT****                    ****STACK TOP WINDS (EXTRAPOLATED FROM  10.0 METERS)****
STABILITY  WIND SPEED  MAX CONC      DIST OF MAX  PLUME HT     WIND SPEED  MAX CONC      DIST OF MAX  PLUME HT
           (M/SEC)     (G/CU M)      (KM)         (M)          (M/SEC)     (G/CU M)      (KM)         (M)
    1        0.50    2.5584E-04       1.426     919.0(2)         0.55    2.4954E-04       1.282     837.7(2)
    1        0.80    2.7610E-04       1.042     589.4(2)         0.88    2.8469E-04       0.999     538.6(2)
    1        1.00    2.9586E-04       0.945     479.5(2)         1.10    3.0440E-04       0.906     438.8(2)
    1        1.50    3.3066E-04       0.796     333.0(2)         1.65    3.3845E-04       0.764     305.9(2)
    1        2.00    3.5270E-04       0.707     259.7(2)         2.20    3.5928E-04       0.681     239.4(2)
    1        2.50    3.6700E-04       0.648     215.8(2)         2.75    3.7219E-04       0.624     199.5
    1        3.00    3.8693E-04       0.555     179.1            3.31    4.0344E-04       0.531     162.5

                    ****WINDS CONSTANT WITH HEIGHT****                    ****STACK TOP WINDS (EXTRAPOLATED FROM  10.0 METERS)****
STABILITY  WIND SPEED  MAX CONC      DIST OF MAX  PLUME HT     WIND SPEED  MAX CONC      DIST OF MAX  PLUME HT
           (M/SEC)     (G/CU M)      (KM)         (M)          (M/SEC)     (G/CU M)      (KM)         (M)
    2        0.50    8.6753E-05       5.712     919.0(2)         0.55    9.0815E-05       4.990     837.7(2)
    2        0.80    1.1703E-04       3.551     589.4(2)         0.88    1.2496E-04       3.270     538.6(2)
    2        1.00    1.3585E-04       2.940     479.5(2)         1.10    1.4466E-04       2.712     438.8(2)
    2        1.50    1.7501E-04       2.107     333.0(2)         1.65    1.8518E-04       1.950     305.9(2)
    2        2.00    2.0575E-04       1.679     259.7(2)         2.20    2.1641E-04       1.559     239.4(2)
    2        2.50    2.3028E-04       1.418     215.8(2)         2.75    2.4086E-04       1.320     199.5
    2        3.00    2.5000E-04       1.241     186.5            3.31    2.6014E-04       1.158     172.9
    2        4.00    2.7878E-04       1.016     149.9            4.41    2.8738E-04       0.953     139.7
    2        5.00    2.9741E-04       0.879     127.9            5.51    3.0410E-04       0.828     119.8

                    ****WINDS CONSTANT WITH HEIGHT****                    ****STACK TOP WINDS (EXTRAPOLATED FROM  10.0 METERS)****
STABILITY  WIND SPEED  MAX CONC      DIST OF MAX  PLUME HT     WIND SPEED  MAX CONC      DIST OF MAX  PLUME HT
           (M/SEC)     (G/CU M)      (KM)         (M)          (M/SEC)     (G/CU M)      (KM)         (M)
    3        2.00    1.5711E-04       3.343     259.7(2)         2.30    1.7218E-04       2.944     231.3(2)
    3        2.50    1.8160E-04       2.728     215.8(2)         2.87    1.9728E-04       2.415     193.0
    3        3.00    2.0224E-04       2.325     186.5            3.45    2.1791E-04       2.068     167.5
    3        4.00    2.3432E-04       1.830     149.9            4.59    2.4877E-04       1.640     135.6
    3        5.00    2.5703E-04       1.538     127.9            5.74    2.6940E-04       1.388     116.5
    3        7.00    2.8382E-04       1.210     102.8            8.04    2.9119E-04       1.106      94.7
    3       10.00    2.9750E-04       0.969      83.9           11.49    2.9793E-04       0.898      78.3
    3       12.00    2.9747E-04       0.877      76.6           13.78    2.9419E-04       0.818      71.9
    3       15.00    2.9085E-04       0.786      69.3           17.23    2.8332E-04       0.739      65.5
```

Figure 7. Batch output of example calculation.

STABILITY	****WINDS CONSTANT WITH HEIGHT**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)	****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
4	0.50	9.9990E+09	999.999(3)	919.0(2)	0.62	1.1091E-05	98.419	754.0(2)
4	0.80	1.6511E-05	60.481	589.4(2)	0.98	2.2524E-05	41.362	486.2(2)
4	1.00	2.3036E-05	40.220	479.5(2)	1.23	3.1073E-05	29.491	397.0(2)
4	1.50	3.9940E-05	21.551	333.0(2)	1.85	5.1505E-05	15.612	278.0(2)
4	2.00	5.6601E-05	13.842	259.7(2)	2.46	7.1708E-05	10.160	218.5(2)
4	2.50	7.2915E-05	10.000	215.8(2)	3.08	8.9369E-05	7.819	182.8
4	3.00	8.7243E-05	8.086	186.5	3.69	1.0524E-04	6.197	159.0
4	4.00	1.1252E-04	5.618	149.9	4.92	1.3204E-04	4.390	129.2
4	5.00	1.3348E-04	4.314	127.9	6.16	1.5290E-04	3.429	111.4
4	7.00	1.6431E-04	3.000	102.8	8.62	1.7899E-04	2.553	91.0
4	10.00	1.8725E-04	2.252	83.9	12.31	1.9511E-04	1.916	75.7
4	12.00	1.9439E-04	1.953	76.6	14.77	1.9803E-04	1.686	69.7
4	15.00	1.9810E-04	1.669	69.3	18.47	1.9640E-04	1.468	63.8
4	20.00	1.9449E-04	1.402	62.0	24.62	1.8654E-04	1.260	57.8

STABILITY	****WINDS CONSTANT WITH HEIGHT**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)	****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
5	2.00	1.8946E-04	9.923	131.0	3.25	1.5788E-04	7.988	117.4
5	2.50	1.7455E-04	8.963	124.5	4.06	1.4443E-04	7.259	111.8
5	3.00	1.6286E-04	8.280	119.5	4.87	1.3395E-04	6.715	107.6
5	4.00	1.4532E-04	7.298	112.2	6.50	1.1837E-04	5.968	101.4
5	5.00	1.3251E-04	6.644	107.0	8.12	1.0711E-04	5.466	97.0

STABILITY	****WINDS CONSTANT WITH HEIGHT**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)	****STACK TOP WINDS (EXTRAPOLATED FROM 10.0 METERS)**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
6	2.00	1.2707E-04	19.741	115.5	4.29	1.0491E-04	14.999	98.5
6	2.50	1.2143E-04	17.010	110.1	5.36	9.6261E-05	13.952	94.4
6	3.00	1.1662E-04	15.082	105.9	6.43	8.9407E-05	12.821	91.1
6	4.00	1.0748E-04	14.999	99.9	8.57	7.9123E-05	11.280	86.5
6	5.00	9.8931E-05	14.410	95.6	10.72	7.1622E-05	10.241	83.1

(1) THE DISTANCE TO THE POINT OF MAXIMUM CONCENTRATION IS SO GREAT THAT THE SAME STABILITY IS NOT LIKELY TO PERSIST LONG ENOUGH FOR THE PLUME TO TRAVEL THIS FAR.

(2) THE PLUME IS CALCULATED TO BE AT A HEIGHT WHERE CARE SHOULD BE USED IN INTERPRETING THE COMPUTATION.

(3) NO COMPUTATION WAS ATTEMPTED FOR THIS HEIGHT AS THE POINT OF MAXIMUM CONCENTRATION IS GREATER THAN 100 KILOMETERS FROM THE SOURCE.

Figure 7. (continued)

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APPENDIX A

MODELING CONCEPTS

BASIC CONCEPTS

Meteorological factors of wind and turbulence are important in the dispersion process. The dispersion of pollutants emitted into the atmosphere depends on the turbulent mixing that takes place between the polluted air and its cleaner surroundings. This turbulent mixing occurs primarily through eddy dispersion by the circular motions (eddies) that exist in many sizes in the atmosphere, which tend to break portions from the volume of polluted air and mix them with clean air.

In addition to meteorological factors, other factors are significant in modeling the dispersion process and pollutant concentrations. Source characteristics and surface roughness features, as well as topography, are among the interrelated factors that determine the pollutant concentration field.

Source-Related Factors

An important parameter related to pollutant concentrations is the rate of emission of the pollutant from the source. Concentrations are directly proportional to emission rate, usually expressed as mass per unit time. The effective height of release is also important. Roughly, the maximum ground-level concentration is inversely proportional to the square of the height of release. The effective height of release is the combination of physical release height and any additional rise due to buoyancy or momentum effects. The buoyancy of a hot plume will usually dominate over the effect of momentum. Buoyant plume rise is affected by the excess of the stack gas temperature above the ambient air temperature and the volume flow of stack gases. Buoyant rise also decreases with increasing wind speed and is affected by the thermal stability of the air above the plume. Momentum rise is important for plumes with little excess temperature and is proportional to stack gas velocity and stack diameter.

Over relatively flat terrain, a higher effective stack height decreases ground-level concentrations and causes the maximum concentration to occur farther from the source. Effective heights are raised by increasing the physical stack height, the

stack gas temperature, the volume of exit gases (without decreasing the exit temperature), or the stack gas exit velocity.

Meteorological Factors

Wind direction is a primary variable in determining concentrations at specific receptors, because it determines whether transport takes place from the source towards the general direction of the receptor. Concentrations from line and area sources are less sensitive to wind direction than are concentrations from point sources.

Wind speed dilutes air pollutants from continuous sources as the plume emerges from the stack. With increasing wind speed, the pollutant concentrations in the plume become more dilute.

Both mechanical production of turbulence and buoyant production or loss of turbulence are important in pollutant dispersion. Mechanical turbulence results from wind flow over objects. The number, size, and spacing of the objects or roughness elements influence the growth of mechanical turbulence. When roughness elements are close together, like trees in a forest, mechanical turbulence is not enhanced, because a new interface forms, allowing the air to flow smoothly over the objects. Mechanical turbulence is enhanced in regions where large objects like mountains or skyscrapers disturb the general air flow. In general, an increase of wind speed will increase the mechanical turbulence.

In light-wind situations, the heating or cooling of the earth's surface increases the importance of buoyantly produced turbulence to dispersion processes. As the sun heats the surface, the air next to the surface is heated and rises buoyantly. During times of strong surface heating, commonly referred to as unstable conditions, buoyant turbulence is produced by the rising thermals of heated air, further amplifying the mechanical turbulence. Furthermore, strong surface heating leads to superadiabatic lapse rates (see Glossary) which encourage the formation of convective cells. Rising thermals are carried upwards in narrow convective updrafts. A general region of subsiding air surrounds these narrow columns. Thus, in unstable conditions, a plume spreads over a relatively large vertical distance.

At nighttime, radiant heat loss at the surface cools the air near the ground. In such situations, commonly referred to as stable conditions, a temperature inversion exists. Further, buoyant turbulence is not produced, and mechanically induced turbulence is suppressed. Thus, a plume spreads little vertically in stable conditions.

In a temperature structure where the air is neither heated nor cooled, turbulence is neither amplified nor suppressed. These conditions are commonly referred to as neutral.

Pasquill (1961) devised a method for classifying turbulence in terms of atmospheric conditions into six stability categories, ranging from very unstable (class A), to neutral (class D), to moderately stable (class F) (see Table A-1). For PTPLU, the dispersion due to atmospheric turbulence is assumed to be related to the Pasquill stability classes.

Wind speed generally increases with height above the surface, and this increase depends on both surface roughness and atmospheric stability. A power-law profile of the form

$$u(z) = u(z_a)(z/z_a)^p$$

is frequently used to approximate this increase. The wind speed at a height z above the ground is $u(z)$; $u(z_a)$ is the wind speed measured at the anemometer height, z_a, above the ground; and p is a function of stability. For a more detailed discussion of wind profiles, see Irwin (1979).

Another condition that affects vertical dispersion is the thickness of the neutral or unstable layer, often referred to as the mixing layer. At the top of the convective layer, an inversion usually exists, tending to damp out vertical motions and limiting the extent to which pollutants can spread vertically. The strength and depth of the inversion are also important; if the inversion is weak or shallow, pollutants may still diffuse through it.

The mixing height varies both seasonally and diurnally. It is typically high in summer and at mid-day and low in winter, and it frequently is undefined at night (when a surface-based inversion exists). For a climatological summary of mixing heights across the United States see Holzworth (1972).

Further Considerations

Usually, the wind turns with height, due primarily to friction of the wind with the ground. Friction causes slowing of the wind near the surface, which causes the low-level flow to deviate toward low pressure. This results in a clockwise turning of the wind with height. Other forces also cause turning of the wind with height. Within a barotropic atmosphere (in which the surfaces of constant pressure are also surfaces of constant density), the wind direction is constant with height, except near the surface, where frictional effects take place. The atmosphere is usually not barotropic; when surfaces of constant pressure and constant density do not coincide, the atmosphere is said to be baroclinic. In such an atmosphere, the wind direction must vary

with height, since colder air is advected (transported horizontally) into warmer surroundings (or warmer air into colder surroundings). During cold-air advection, the wind direction backs (counterclockwise rotation) with height, and during warm-air advection, the wind direction veers (clockwise rotation) with height. Vertical wind shear causes portions of a polluted plume that has dispersed to different altitudes to be transported away from the source in different directions, resulting in additional horizontal spreading or dispersion. Because effects of wind direction shear are ignored in the model presented here, estimates of concentration directly downwind of sources are likely to be higher than concentrations actually observed at distances greater than 10 km from the source. Methods to account for the effect of wind direction shear are discussed by Pasquill (1976).

Besides causing wind direction shear, the frictional effect also causes a wind speed shear, with the wind speed decreasing near the earth's surface (to zero at the surface). Under stable conditions, the increase of speed with height to the wind speed of the free atmosphere may take place through a shallow layer, only 100 to 200 m thick. This also tends to be the case if the surface is smooth. Under conditions of instability or large surface roughness, the transition takes place through a much deeper layer. The combined effects of stability and surface roughness result in different patterns of wind speed with time of day at different heights. For example, wind speeds near the ground (10 m) generally exhibit a nighttime minimum and a daytime maximum. At greater heights (e.g., 200 m above ground), wind speeds may reach a minimum (maximum surface friction effect) during mid-afternoon and a maximum (nearest the free atmosphere speed) at night.

In considering buoyant production or suppression of turbulence as reflected in the vertical temperature structure, it is important to realize that the layer adjacent to the ground surface characterizes the state of the atmosphere. For instance, when conditions are very unstable, the temperature structure through the well-mixed convective layer (typically on the order of 1000 to 2000 m thick) is nearly adiabatic, indicating that turbulent motion is neither suppressed nor enhanced. Only within the near-surface layer (typically 100 m thick or less) is the temperature structure superadiabatic. If one attempted to specify the state of the atmosphere using the temperature structure in the higher layers, one would erroneously conclude that the atmosphere was nearly neutral, when in fact it was convectively unstable. During stable conditions, the temperature structure above the surface-based inversion is often nearly adiabatic. Hence, during stable conditions, the temperature structure within the layers aloft may not truly reflect how stable the entire dispersion layer is. Therefore, in considering ground-level concentrations from point sources, it is important

to examine the surface layer near the ground to properly determine the influences of buoyant production or loss of turbulent kinetic energy on dispersion through the surface layer.

Information about conditions above the ground is by no means useless. On the contrary, detailed structures of temperature and wind velocity with height are extremely useful for assessing air pollution transport and dispersion; but they are most useful when interpreted with near-surface measurements.

Air pollution simulations are frequently complicated by local flows. Uneven solar heating on the sides of valleys or cold-air drainage at night can cause small-scale circulations that may make analysis of meteorological measurements difficult. For example, during the Lewiston, Idaho -- Clarkston, Washington study (U. S. Department of Health, Education, and Welfare, 1964), maximum ground-level concentrations were observed at a receptor down-valley from the source at the time when surface wind measurements indicated an up-valley flow. Thorough analysis, revealed that the high concentrations were due to the fumigation (rapid downward mixing) of the detached plume, which had been flowing down-valley during the night. The plume was not mixed downward to the valley floor until the winds had already shifted to up-valley.

Another cause of local circulations is land-water interfaces, which can produce land and sea breezes, due to horizontal temperature differences, especially during periods of light general wind flow.

The effects of local flow are sufficiently complex to require a special modeling approach for each condition.

GAUSSIAN EQUATIONS FOR ESTIMATING CONCENTRATIONS

In using the Gaussian plume model, one assumes that pollutant concentrations from a continuously emitted plume are proportional to emission rate, and are diluted by the wind at the point of emission at a rate inversely proportional to the wind speed. One also assumes that the time-averaged (over approximately one hour) pollutant concentrations crosswind and in the vertical near the source are closely described by Gaussian or normal distributions. The standard deviations of a plume concentration in these two directions are empirically related to the levels of turbulence in the atmosphere and increase with distance from the source.

In its simplest form, the Gaussian model is based on the assumption that the pollutant does not undergo chemical reactions or other removal processes during its transport from the source. Furthermore, pollutants reaching the ground or the top of the mixing height as the plume grows are assumed to be eddy-reflected

back toward the plume centerline.

The three Gaussian equations given below are based on a coordinate scheme with the origin at the base of the stack, x downwind from the source, y crosswind, and z vertical; Figure A-1 illustrates the coordinate system. These equations include four components, from left to right in Eq. A1: 1) concentrations are proportional to emission rate, 2) the released effluent is diluted by the wind passing the point of release, 3) the effluent is spread horizontally, resulting in a Gaussian or normal (bell-shaped) crosswind distribution downwind, and 4) the effluent is spread vertically. Vertical spread also results in a normal vertical distribution near the source, which at greater downwind distances is modified by eddy reflection at the ground and, if appropriate, by eddy reflection at the mixing height.

The following symbols are used:

χ_p -- concentration (grams per cubic meter),

Q -- emission rate (grams per second),

u -- wind speed (meters per second),

σ_y -- standard deviation of plume concentration distributed in the horizontal (evaluated at distance x and for the appropriate stability) (meters),

σ_z -- standard deviation of plume concentration distributed in the vertical (evaluated at distance x and for the appropriate stability) (meters),

L -- mixing height (meters),

H -- effective height of emission (meters),

z -- receptor height above ground (meters), and

y -- crosswind distance from plume centerline (meters).

The concentration, χ_p, at a receptor at (x,y,z) from the continuous emission from a point source located at (0,0,H) is given by one of the three following equations.

For stable conditions or unlimited mixing,

$$\chi_p = Q \cdot 1/u \cdot g_1/(\sqrt{2\pi}\ \sigma_y) \cdot g_2/(\sqrt{2\pi}\ \sigma_z), \qquad \text{(A1)}$$

where

$$g_1 = \exp(-0.5\ y^2/\sigma_y^2), \text{ and}$$

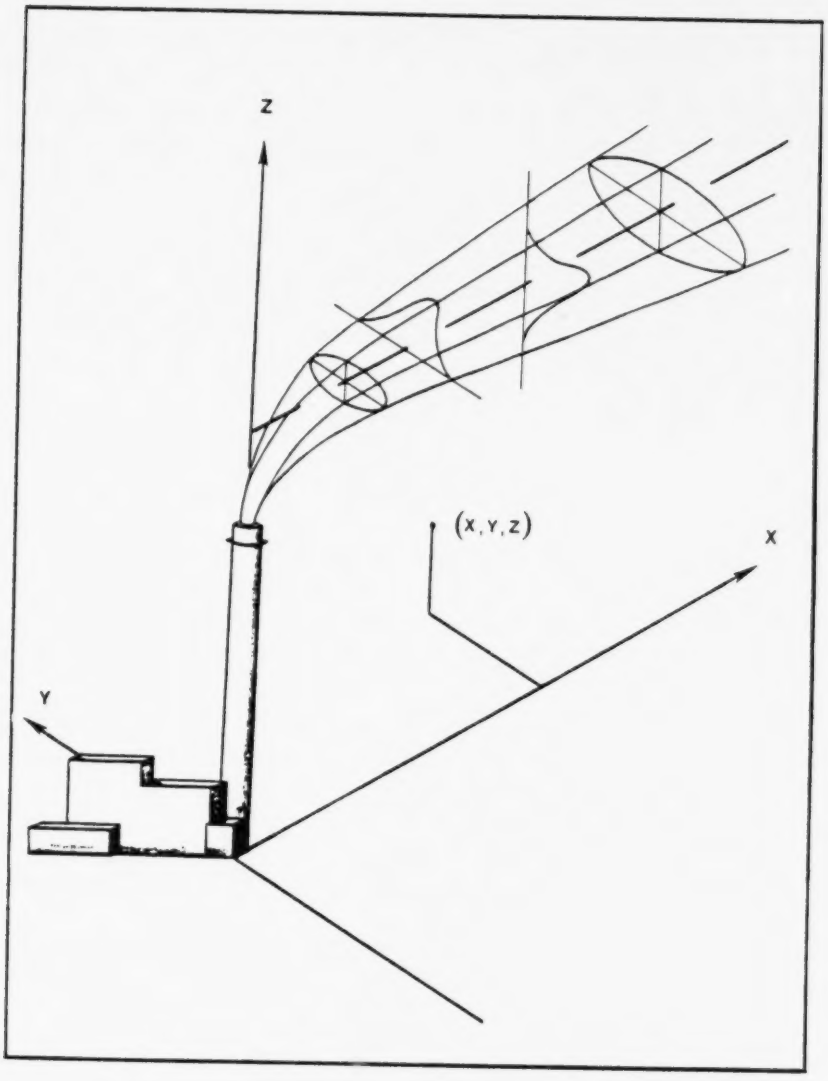

Figure A-1. Coordinate system showing Gaussian distributions in the horizontal and vertical.

$$g_2 = \exp[-0.5(z-H)^2/\sigma_z^2] + \exp[-0.5(z+H)^2/\sigma_z^2].$$

Note that if y = 0, or z = 0, or both z and H are 0, this equation simplifies greatly.

For unstable or neutral conditions, where σ_z is greater than 1.6 L,

$$\chi_p = Q \cdot 1/u \cdot g_1/(\sqrt{2\pi}\ \sigma_y) \cdot 1/L. \qquad (A2)$$

For unstable or neutral conditions, provided that both H and z are less than L, where σ_z is less than or equal to 1.6 L,

$$\chi_p = Q \cdot 1/u \cdot g_1/(\sqrt{2\pi}\ \sigma_y) \cdot g_3/(\sqrt{2\pi}\ \sigma_z), \qquad (A3)$$

where

$$g_3 = \sum_{N=-\infty}^{\infty} \{\exp[-0.5(z-H+2NL)^2/\sigma_z^2] + \exp[-0.5(z+H+2NL)^2/\sigma_z^2]\}.$$

(This infinite series converges rapidly, and evaluation with N varying from -4 to +4 is usually sufficient.)

When estimates are calculated by hand, Eq. A1 is frequently applied until σ_z = 0.8 L, and then Eq. A2 is applied for all distances where σ_z exceeds 0.8 L. This causes an inflection point in a plot of concentrations with distance. Adding Eq. A3, which includes multiple eddy reflections, and changing the criteria for use of Eq. A2 to situations where σ_z is greater than 1.6 L results in a smooth transition to uniform mixing, regardless of source or receptor height. Values must be obtained for the dispersion parameters in the above equations. In his original discussions of dispersion and in his subsequent writings, Pasquill (1961, 1974, 1976) emphasized the desirability of using direct measurements of turbulent intensity to characterize atmospheric dispersion. Typically, we lack the required turbulence measurements and resort to other methods of estimating the parameters. Although not expressed as standard deviations for use with Gaussian equations, Pasquill (1961) provided some estimates of dispersion qualified by, "for use in the likely absence of special measurements of wind structure there was clearly a need for broad estimates of θ and h in terms of routine meteorological data." Pasquill's parameters of spreading are θ and h. Gifford (1960) transformed Pasquill's parameters to σ_y and σ_z for use with Gaussian equations. Commonly referred to as the Pasquill-Gifford (P-G) dispersion parameters, these are discussed later in this appendix.

By differentiating Eq. A1 with respect to distance, x, and setting the derivative equal to zero, an equation for maximum concentration can be derived:

$$\chi_{max} = 2Q\sigma_z/\sigma_y e\pi u H^2;$$

the distance to maximum concentration is the distance where $\sigma_z = H/\sqrt{2}$. However, this equation is correct only if the ratio of σ_z/σ_y is constant with distance (see Pasquill (1974), p. 273, for further details). For the P-G parameter values, the ratio is not constant, and maximum concentrations, if required, are determined using iterative methods.

PLUME RISE FOR POINT SOURCES

The use of the methods of Briggs to estimate plume rise and effective height of emission are discussed below.

First, actual or estimated wind speed at stack top, u(h), is assumed to be available.

Stack Downwash

To consider stack downwash, the physical stack height is modified following Briggs (1973, p. 4). The h' is found from

$$h' = h + 2\{[v_s/u(h)] - 1.5\}d \quad \text{for} \quad v_s < 1.5u(h), \qquad \text{(A4)}$$

$$h' = h \text{ for } v_s \geq 1.5u(h),$$

where h is physical stack height (meters), v_s is stack gas velocity (meters per second), and d is inside stack-top diameter (meters). This h' is used throughout the remainder of the plume height computation. If stack downwash is not considered, h' = h in the following equations.

Buoyancy Flux

For most plume rise situations, the value of the Briggs buoyancy flux parameter, F (m^4/s^3) is needed. The following equation is equivalent to Briggs' (1975, p. 63) Eq. 12:

$$F = (gv_s d^2 \Delta T)/(4T_s), \qquad \text{(A5)}$$

where $\Delta T = T_s - T$, T_s is stack gas temperature (kelvin), and T is ambient air temperature (kelvin).

Unstable or Neutral: Crossover Between Momentum and Buoyancy

For cases with stack gas temperature greater than or equal to ambient air temperature, it must be determined whether the plume rise is dominated by momentum or buoyancy. The crossover temperature difference $(\Delta T)_c$ is determined for 1) F less than 55 and 2) F greater than or equal to 55. If the difference between stack gas temperature and ambient air temperature, ΔT, exceeds or equals the $(\Delta T)_c$, plume rise is assumed to be buoyancy dominated;

if the difference is less than $(\Delta T)_c$, plume rise is assumed to be momentum dominated (see below).

The crossover temperature difference is found by setting Briggs' (1969, p. 59) Eq. 5.2 equal to the combination of Briggs' (1971, p. 1031) Eqs. 6 and 7 and solving for ΔT. For F less than 55,

$$(\Delta T)_c = 0.0297 v_s^{1/3} T_s / d^{2/3}. \quad \text{(A6)}$$

For F equal to or greater than 55,

$$(\Delta T)_c = 0.00575 v_s^{2/3} T_s / d^{1/3}. \quad \text{(A7)}$$

Unstable or Neutral: Buoyancy Rise

For situations where ΔT exceeds or is equal to $(\Delta T)_c$ as determined above, buoyancy is assumed to dominate. The distance to final rise x_f (in kilometers) is determined from the equivalent of Briggs' (1971, p. 1031) Eq. 7, and the distance to final rise is assumed to be $3.5x^*$, where x^* is the distance at which atmospheric turbulence begins to dominate entrainment. For F less than 55,

$$x_f = 0.049 F^{5/8}. \quad \text{(A8)}$$

For F equal to or greater than 55,

$$x_f = 0.119 F^{2/5}. \quad \text{(A9)}$$

The plume height, H (in meters), is determined from the equivalent of the combination of Briggs' (1971, p. 1031) Eqs. 6 and 7. For F less than 55,

$$H = h' + 21.425 F^{3/4} / u(h). \quad \text{(A10)}$$

For F equal to or greater than 55,

$$H = h' + 38.71 F^{3/5} / u(h). \quad \text{(A11)}$$

Unstable or Neutral: Momentum Rise

For situations where the stack gas temperature is less than the ambient air temperature, it is assumed that the plume rise is dominated by momentum. Also, if ΔT is less than $(\Delta T)_c$ from Eq. A6 or A7, it is assumed that the plume rise is dominated by momentum. The plume height is calculated from Briggs' (1969, p. 59) Eq. 5.2:

$$H = h' + 3 d v_s / u(h). \quad \text{(A12)}$$

Briggs (1969) suggests that this equation is most applicable when

v_s/u is greater than 4. Since momentum rise occurs quite close to the point of release, the distance to final rise is set equal to zero.

Stability Parameter

For stable situations, the stability parameter s is calculated from the equation (Briggs, 1971, p. 1031):

$$s = g(\partial\theta/\partial z)/T. \qquad \text{(A13)}$$

As an approximation, for stability class E (or 5), $\partial\theta/\partial z$ is taken as 0.02 K/m, and for stability class F (or 6), $\partial\theta/\partial z$ is taken as 0.035 K/m.

Stable: Crossover Between Momentum and Buoyancy

For cases with stack gas temperature greater than or equal to ambient air temperature, it must be determined whether the plume rise is dominated by momentum or buoyancy. The crossover temperature difference $(\Delta T)_c$ is found by setting Briggs' (1975, p. 96) Eq. 59 equal to Briggs' (1969, p. 59) Eq. 4.28, and solving for ΔT. The result is

$$(\Delta T)_c = 0.019582 v_s T s^{1/2}. \qquad \text{(A14)}$$

If the difference between stack gas temperature and ambient air temperature (ΔT) exceeds or equals $(\Delta T)_c$, the plume rise is assumed to be buoyancy dominated; if ΔT is less than $(\Delta T)_c$, the plume rise is assumed to be momentum dominated.

Stable: Buoyancy Rise

For situations where ΔT is greater than or equal to $(\Delta T)_c$, buoyancy is assumed to dominate. The distance to final rise (in kilometers) is determined by the equivalent of a combination of Briggs' (1975, p. 96) Eqs. 48 and 59:

$$x_f = 0.0020715 u(h) s^{-1/2}. \qquad \text{(A15)}$$

The plume height is determined by the equivalent of Briggs' (1975, p. 96) Eq. 59:

$$H = h' + 2.6\{F/[u(h)s]\}^{1/3}. \qquad \text{(A16)}$$

The stable buoyancy rise for calm conditions (Briggs, 1975, pp. 81-82) is also evaluated:

$$H = h' + 4F^{1/4} s^{-3/8}. \qquad \text{(A17)}$$

The lower of the two values obtained from Eqs. A16 and A17 is taken as the final effective height.

By setting Eqs. A16 and A17 equal to each other and solving for u(h), one can determine the wind speed that yields the same plume rise for the wind conditions (A16) as does the equation for calm conditions (A17). This wind speed is

$$u(h) = (2.6/4)^3 F^{1/4} s^{1/8}$$

$$= 0.2746 F^{1/4} s^{1/8}. \qquad \text{(A18)}$$

For wind speed less than or equal to this value, Eq. A17 should be used for plume rise; for wind speeds greater than this value, Eq. A16 should be used.

Stable: Momentum Rise

When the stack gas temperature is less than the ambient air temperature, it is assumed that the plume rise is dominated by momentum. If ΔT is less than $(\Delta T)_c$ as determined by Eq. A14, it is also assumed that the plume rise is dominated by momentum. The plume height is calculated from Briggs' (1969, p. 59) Eq. 4.28:

$$H = h' + 1.5\{(v_s^2 d^2 T)/[4T_s u(h)]\}^{1/3} s^{-1/6}. \qquad \text{(A19)}$$

The equation for unstable or neutral momentum rise (A12) is also evaluated. The lower result of these two equations is used as the resulting plume height.

All Conditions: Distance Less than Distance to Final Rise (Gradual Rise)

Where gradual rise is to be estimated for unstable, neutral or stable conditions, if the distance upwind from receptor to source x (in kilometers), is less than the distance to final rise, the equivalent of Briggs' (1971, p. 1030) Eq. 2 is used to determine plume height:

$$H = h' + (160 F^{1/3} x^{2/3})/u(h). \qquad \text{(A20)}$$

This height is used only for buoyancy-dominated conditions; should it exceed the final rise for the appropriate condition, the final rise is substituted instead.

DISPERSION PARAMETERS

PTPLU uses the method presented by Pasquill (1961) to estimate the dispersion potential of the atmosphere. In this method, six stability categories are specified in terms of wind speed and solar radiation. Stability categories are given in Table A-1. Class A is the most unstable and class F the most stable.

TABLE A-1. KEY TO STABILITY CATEGORIES FROM PASQUILL (1961)*

Surface wind speed (at 10m) (m/s)	Day			Night†	
	Incoming solar radiation			Thinly overcast or 4/8 low cloud	3/8 or less cloud
	Strong	Moderate	Slight		
< 2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

* The neutral class, D, should be used for overcast conditions during day or night.

† Night refers to the period from one hour before sunset to one hour after sunrise.

The lateral and vertical dispersion parameters are those computed by Gifford (1960) from the original plume spreading parameters reported by Pasquill (1961). The relevant background of the P-G curves is summarized by Pasquill (1976) and is given in Table A-2. It should be noted from Table A-2 that vertical dispersion estimates were based on surface release of material.

The algorithms employed by PTPLU to evaluate the horizontal and vertical dispersion parameters are discussed next. Similar algorithms are employed by MPTER, RAM, PTDIS, and PTMTP.

One of the assumptions of Gaussian plume modeling is that concentrations within the plume vary vertically and horizontally according to a normal distribution, with the maximum concentrations along the plume centerline. In converting plume dimensions to standard deviations, Gifford assumed that the edge of the plume is equivalent to the point where the concentration is 1/10 of the centerline concentration at the same distance from the source. This is equivalent to 2.15 σ.

Vertical Dispersion

The P-G curves describing the vertical spread of plumes have been shown to fit an exponential equation of the form

$$\sigma_z = ax^b,$$

where x is the downwind distance. Values of a and b vary with stability class and range of downwind distance. The vertical dispersion parameter is set to 5000 m for stability class A at distances greater than 3.11 km and for stability class B at

TABLE A-2. BASIS AND SCOPE OF THE ORIGINAL P-G CURVES FROM PASQUILL (1976)

Crosswind spread	
Source height	Any (within mixed layer).
Sampling time	3 min.
Basis for x = 0.1 to 1 km	Preliminary statistics of wind direction fluctuation for a surface roughness length of 3 cm.
Basis for x = 10 to 100 km	Extrapolation of short-range data in the light of limited special observations of tracer dispersion over level terrain of mixed roughness (implied roughness length of 30 cm).
Vertical spread	
Source height	Effectively zero (surface release of material), but offered as usable for any height in a mixed layer, in the absence of strong evidence to the contrary.
Sampling time	Any. For elevated sources up to about 100 m, the limiting sampling time is roughly proportional to the height of the source; if the height of the source is above 100 m, the sampling time is roughly 10 min.
Basis for x = 0.1 to 1 km	Properties of the wind profile over a surface of small roughness (roughness length of 3 cm), with guidance from dispersion studies, especially in regard to the effect of thermal stratification.
Basis for x = 10 to 100 km	As for the crosswind spread, with guidance from early data on the properties of the vertical component of turbulence at heights throughout the mixed layer.

distances greater than 35 km. Table A-3 shows the constants employed by PTPLU. It should be noted that the program limits the vertical dispersion parameter to 5000 m.

Lateral Dispersion

Lateral dispersion has been estimated at 0.1 km and 100 km by measuring the half-angle from the plume centerline to the edge of the plume at 2.15 standard deviations. Lateral dispersion for any downwind distance less than 100 km can be estimated by linear interpolation, with the half-angle as the ordinate and the logarithm of the downwind distance as the abscissa. The tangent of this angle is 2.15 standard deviations divided by the downwind distance. Using these facts, the horizontal dispersion parameter (in meters) can be obtained from the interpolated half-angle as follows:

$$\sigma_y = 1000 \times \tan(\theta)/2.15,$$

where x is the downwind distance in kilometers.

The half-angles (degrees) employed by the model at 0.1 km and 100 km for each stability class are

Stability class	0.1 km	100 km
A	30.0	12.50
B	22.5	10.00
C	15.0	7.50
D	10.0	5.00
E	7.5	3.75
F	5.0	2.50

Figure A-2 graphically represents the equations for the half-angle. Although commom logarithms are used in this figure, the program employs the natural logarithm of downwind distance for the abscissa. Therefore, the corresponding values to 0.1 and 100 km are -2.30 and 4.6. As an example, the equation used to determine the half-angle for stability A is obtained as follows:

$$\theta = a \ln(x) + b,$$

where

$$a = [(12.50 - 30.0)/(4.6 + 2.3)]$$
$$b = 30 + 2.3a,$$

and

$$\theta = -2.5334 \ln(x) + 24.167.$$

TABLE A-3. CONSTANTS FOR THE VERTICAL DISPERSION PARAMETER EQUATION

Stability class	Distance (km)	a	b
A	< 0.1	122.80	0.9447
	0.1 - 0.15	158.08	1.0542
	0.15 - 0.2	170.22	1.0932
	0.2 - 0.25	179.52	1.1262
	0.25 - 0.3	217.41	1.2644
	0.3 - 0.4	258.89	1.4094
	0.4 - 0.5	346.75	1.7283
	> 0.5	453.85	2.1166
B	< 0.2	90.673	0.93198
	0.2 - 0.4	98.483	0.98332
	> 0.4	109.300	1.09710
C		61.141	0.91465
D	< 0.3	34.459	0.86974
	0.3 - 1	32.093	0.81066
	1 - 3	32.093	0.64403
	3 - 10	33.504	0.60486
	10 - 30	36.650	0.56589
	> 30	44.053	0.51179
E	< 0.1	24.260	0.83660
	0.1 - 0.3	23.331	0.81956
	0.3 - 1	21.628	0.75660
	1 - 2	21.628	0.63077
	2 - 4	22.534	0.57154
	4 - 10	24.703	0.50527
	10 - 20	26.970	0.46713
	20 - 40	35.420	0.37615
	> 40	47.618	0.29592
F	< 0.2	15.209	0.81558
	0.2 - 0.7	14.457	0.78407
	0.7 - 1	13.953	0.68465
	1 - 2	13.953	0.63227
	2 - 3	14.823	0.54503
	3 - 7	16.187	0.46490
	7 - 15	17.836	0.41507
	15 - 30	22.651	0.32681
	30 - 60	27.074	0.27436
	> 60	34.219	0.21716

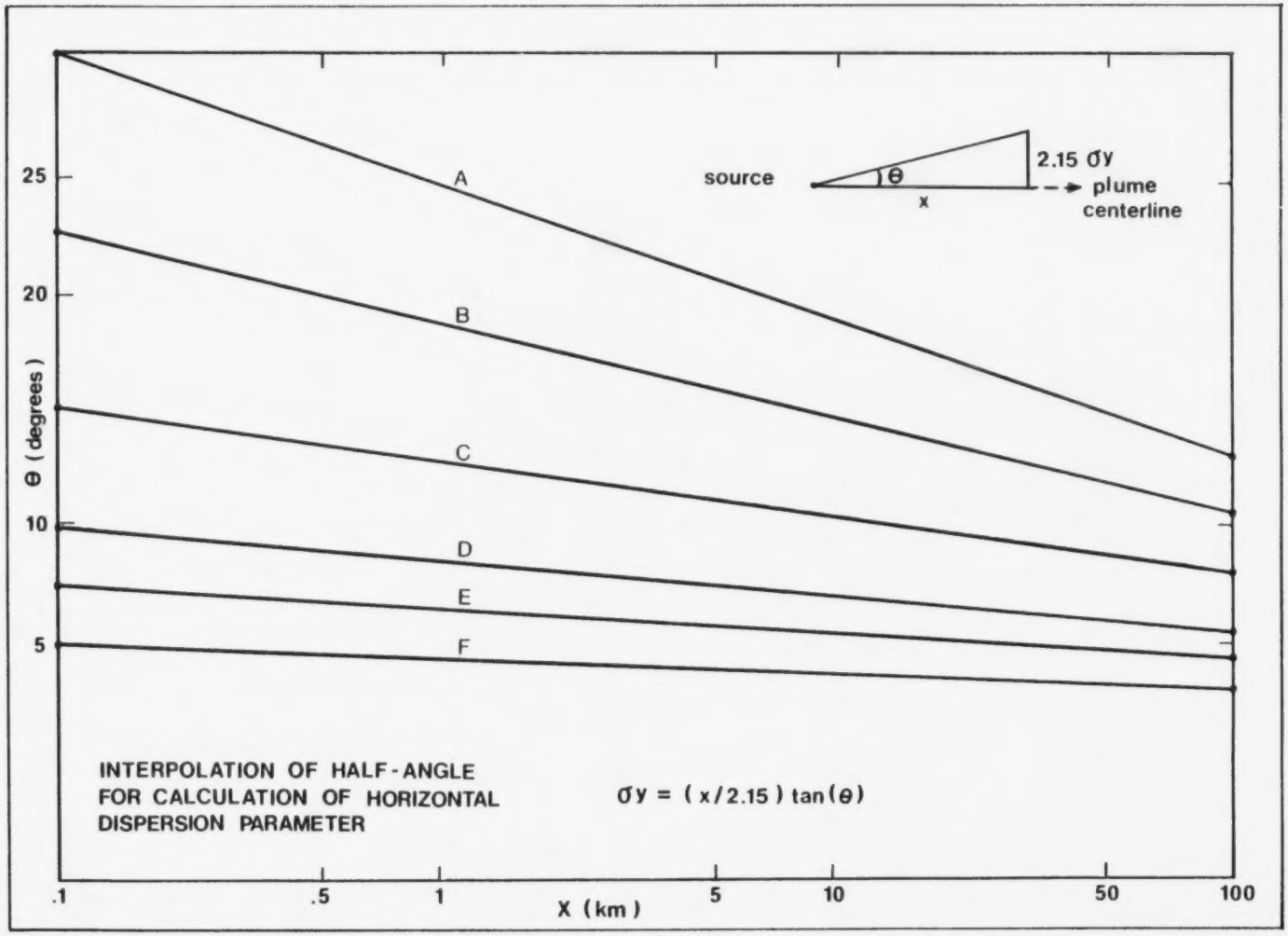

Figure A-2. Estimation of lateral dispersion parameter.

The constants a and b for each stability class are as follows:

Stability class	a	b
A	-2.5334	24.167
B	-1.8096	18.333
C	-1.0857	12.500
D	-0.72382	8.3333
E	-0.54287	6.2500
F	-0.36191	4.1667

BUOYANCY-INDUCED DISPERSION

For strongly buoyant plumes, entrainment as the plume ascends through the ambient air contributes to both vertical and horizontal spread. Pasquill (1976) suggests that this induced dispersion, σ_{zo}, can be approximated by the plume rise divided by 3.5. The effective dispersion can then be determined by adding variances:

$$\sigma_{ze} = (\sigma_{zo}^2 + \sigma_z^2)^{1/2},$$

where σ_{ze} is the effective dispersion, and σ_z is the dispersion due to ambient turbulence levels. At the distance of final rise and beyond, the induced dispersion is constant, based on the height of final rise. At distances closer to the source, gradual plume rise is used to determine the induced dispersion.

Since in the initial growth phases of release, the plume is nearly symmetrical about its centerline, buoyancy-induced dispersion in the horizontal direction, σ_{yo}, equal to that in the vertical direction, is used:

$$\sigma_{yo} = \Delta h/3.5.$$

To yield an effective lateral dispersion value, σ_{ye}, this expression is combined with that for dispersion due to ambient turbulence:

$$\sigma_{ye} = (\sigma_{yo}^2 + \sigma_y^2)^{1/2}.$$

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APPENDIX B

INDEXED LISTING OF FORTRAN SOURCE STATEMENTS (BATCH)

The source code and a cross-referenced listing of the batch version of PTPLU follow. The cross-referenced listing contains all references to statement labels, subprograms, and variables that appear in the source program. Statement numbers appear first in the listing and are in numerical order. Variables, arrays, etc., appear second and are in alphabetical order.

```
00001*      C     PTPLU VERSION 81036                                                    PLB00010
00002*      C     THIS IS THE BATCH VERSION OF PTPLU.                                    PLB00020
00003*      C                                                                            PLB00030
00004*      C     PTPLU ABSTRACT:                                                        PLB00040
00005*      C        PTPLU FEATURES SEVERAL IMPROVEMENTS OF THE PTMAX                    PLB00050
00006*      C        ALGORITHM. THE ANALYSIS OF CONCENTRATION HAS BEEN                   PLB00060
00007*      C        EXPANDED TO INCLUDE COMPUTATIONS BASED ON INCREASED                 PLB00070
00008*      C        WIND SPEED WITH HEIGHT FROM USER INPUT WIND PROFILE                 PLB00080
00009*      C        EXPONENTS. OTHER FEATURES INCLUDE OPTIONS FOR CALCULATION           PLB00090
00010*      C        OF GRADUAL PLUME RISE, STACK DOWNWASH, AND INITIAL                  PLB00100
00011*      C        PLUME SIZE DUE TO BUOYANCY INDUCED DISPERSION.                      PLB00110
00012*      C                                                                            PLB00120
00013*      C     PTPLU AUTHORS:                                                         PLB00130
00014*      C        THOMAS E. PIERCE AND D. BRUCE TURNER                                PLB00140
00015*      C        (ON ASSIGNMENT FROM NOAA)                                           PLB00150
00016*      C        ENVIRONMENTAL OPERATIONS BRANCH (MD - 80)                           PLB00160
00017*      C        METEOROLOGY AND ASSESSMENT DIVISION, ESRL                           PLB00170
00018*      C        ENVIRONMENTAL PROTECTION AGENCY                                     PLB00180
00019*      C                                                                            PLB00190
00020*      C     PTPLU MODIFIED BY:                                                     PLB00200
00021*      C        JOE CATALANO AND FRANK HALE                                         PLB00210
00022*      C        AEROCOMP, INC.                                                      PLB00220
00023*      C        3303 HARBOR BLVD.                                                   PLB00230
00024*      C        COSTA MESA, CA  92626                                               PLB00240
00025*      C                                                                            PLB00250
00026*      C     PTPLU SUPPORTED BY:                                                    PLB00260
00027*      C        ENVIRONMENTAL OPERATIONS BRANCH                                     PLB00270
00028*      C        MAIL DROP 80, EPA                                                   PLB00280
00029*      C        RESRCH TRI PK, NC 27711                                             PLB00290
00030*      C                                                                            PLB00300
00031*      C        PHONE: (919) 541-4564   FTS 629-4564                                PLB00310
00032*      C                                                                            PLB00320
00033*      C         PTPLU INPUT:                                                       PLB00330
00034*      C        DATA IN CARD TYPES  1,2 AND 4 MUST BE SEPARATED BY A SPACE          PLB00340
00035*      C        OR A COMMA TO BE COMPATIBLE WITH UNIVAC'S FREE FORMAT.              PLB00350
00036*      C        ADDITIONAL SOURCES CAN BE COMPUTED WITH EXTRA INPUT OF CARD         PLB00360
00037*      C        TYPES 3 AND 4. TWO BLANK DATA CARDS FOLLOW TO TERMINATE             PLB00370
00038*      C        EXECUTION.                                                          PLB00380
00039*      C                                                                            PLB00390
00040*      C     <<<<<< CARD TYPE ONE (FREE FORMAT) >>>>>>                              PLB00400
00041*      C  VARIABLE      DESCRIPTION                                                 PLB00410
00042*      C   IOPT(1)      GRADUAL RISE OPTION    0: DO NOT COMPUTE GRADUAL RISE       PLB00420
00043*      C                                       1: COMPUTE GRADUAL RISE              PLB00430
00044*      C   IOPT(2)      STACK DOWNWASH OPTION  0: DON'T COMPUTE DOWNWASH            PLB00440
00045*      C                                       1: DO COMPUTE DOWNWASH               PLB00450
00046*      C   IOPT(3)      BUOYANCY INDUCED DISPERSION                                 PLB00460
00047*      C                                       0: NONE COMPUTED                     PLB00470
00048*      C                                       1: USE PASQUILL'S TECHNIQUE          PLB00480
00049*      C   T            AMBIENT AIR TEMPERATURE (DEG, K)                            PLB00490
00050*      C   HL           MIXING HEIGHT (METERS)                                      PLB00500
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00051*  C  Z            RECEPTOR ELEVATION (ABOVE GRND SFC, IN METERS)                PLB00510
00052*  C                                                                             PLB00520
00053*  C   <<<<<< CARD TYPE TWO (FREE FORMAT) >>>>>>                                 PLB00530
00054*  C         ************************************************                    PLB00540
00055*  C         *                IMPORTANT MESSAGE                *                PLB00550
00056*  C         *      CALCULATIONS SUBMITTED TO SATISFY REGULATORY *               PLB00560
00057*  C         *  REQUIREMENTS MAY REQUIRE CERTAIN PARAMETER VALUES *              PLB00570
00058*  C         *  FOR WIND PROFILE EXPONENTS AND THE USE OF CERTAIN *              PLB00580
00059*  C         *  OPTIONS. CHECK WITH THE APPROPRIATE EPA REGIONAL  *              PLB00590
00060*  C         *  OFFICE TO INSURE THAT ACCEPTABLE PARAMETER VALUES *              PLB00600
00061*  C         *  ARE USED IN YOUR RUN.                            *              PLB00610
00062*  C         ************************************************                    PLB00620
00063*  C  HANE          ANEMOMETER HEIGHT (METERS)                                   PLB00630
00064*  C                NORMAL HEIGHT IS TEN METERS                                  PLB00640
00065*  C  PL(I,I=1,6)   WIND PROFILE EXPONENTS                                       PLB00650
00066*  C                (SIX VALUES CORRESPONDING TO EACH STABILITY CLASS)           PLB00660
00067*  C                                                                             PLB00670
00068*  C   <<<<<< CARD TYPE THREE (20A4) >>>>>>                                      PLB00680
00069*  C  ALP           ALPHANUMERIC DATA FOR OUTPUT HEADING (80 CHARACTERS)         PLB00690
00070*  C                                                                             PLB00700
00071*  C   <<<<<< CARD TYPE FOUR (FREE FORMAT) >>>>>>                                PLB00710
00072*  C    Q       SOURCE STRENGTH  (G/SEC)                                         PLB00720
00073*  C    HP      PHYSICAL STACK HEIGHT  (M)                                       PLB00730
00074*  C    TS      STACK GAS TEMPERATURE  (DEG K)                                   PLB00740
00075*  C    VS      STACK GAS VELOCITY  (M/SEC)                                      PLB00750
00076*  C    D       STACK DIAMETER  (M)                                              PLB00760
00077*  C                                                                             PLB00770
00078*  C        PTPLU FLOW RELATIONS                                                 PLB00780
00079*  C                                                                             PLB00790
00080*  C                    PTPLU                                                    PLB00800
00081*  C                      |                                                      PLB00810
00082*  C                      | * READ AND CHECK INPUT DATA                          PLB00820
00083*  C                      |                                                      PLB00830
00084*  C                      | * CALCULATE PORTIONS OF PLUME RISE                   PLB00840
00085*  C                      |                                                      PLB00850
00086*  C              --------| - LOOP FOR EACH STABILITY                            PLB00860
00087*  C              |       |                                                      PLB00870
00088*  C              |  -----| - LOOP FOR CONSTANT WIND SPEEDS WITH HEIGHT          PLB00880
00089*  C              |  |    |                                                      PLB00890
00090*  C              |  |    | * * PH                                               PLB00900
00091*  C              |  |    |                                                      PLB00910
00092*  C              |  |    | * * TPMX                                             PLB00920
00093*  C              |  |    |       |                                              PLB00930
00094*  C              |  |    |       * * PHX                                        PLB00940
00095*  C              |  |    |       |                                              PLB00950
00096*  C              |  |    |       * * RCON                                       PLB00960
00097*  C              |  |    |               |                                      PLB00970
00098*  C              |  |    |               * * PSIG                               PLB00980
00099*  C              |  |    |                                                      PLB00990
00100*  C              |  |    | * ADD CAUTIONARY LABELS                              PLB01000
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00101*                C            |   |   |                                                                  PLB01010
00102*                C            |   ----*                                                                  PLB01020
00103*                C            |       |                                                                  PLB01030
00104*                C            |   ----- - LOOP FOR WIND SPEEDS VARYING WITH HEIGHT                       PLB01040
00105*                C            |   |   |                                                                  PLB01050
00106*                C            |   |   | * * PH                                                           PLB01060
00107*                C            |   |   |                                                                  PLB01070
00108*                C            |   |   | * * TPMX                                                         PLB01080
00109*                C            |   |   |       |                                                          PLB01090
00110*                C            |   |   |       * * PHX                                                    PLB01100
00111*                C            |   |   |       |                                                          PLB01110
00112*                C            |   |   |       * * RCON                                                   PLB01120
00113*                C            |   |   |             |                                                    PLB01130
00114*                C            |   |   |             * * PSIG                                             PLB01140
00115*                C            |   |   |                                                                  PLB01150
00116*                C            |   |   | * ADD CAUTIONARY LABELS                                          PLB01160
00117*                C            |   |   |                                                                  PLB01170
00118*                C            |   ----*                                                                  PLB01180
00119*                C            |       |                                                                  PLB01190
00120*                C            -------*                                                                   PLB01200
00121*                C                    |                                                                  PLB01210
00122*                C                    * WRITE OUTPUT                                                     PLB01220
00123*                C                    |                                                                  PLB01230
00124*                C                   EXIT                                                                PLB01240
00125*                C                                                                                       PLB01250
00126*           1          COMMON /MS/ KST,X,SY,SZ                                                           PLB01260
00127*           2          COMMON /MH/ HP,VS,XFUN,DHU,ME,XFOUSE,DHUTE,DHAUE,DUTE,DHCAE,DHCAF,PLB01270
00128*                     1MF,XFOUSF,DHUTF,DHAUF,DUTF,D                                                      PLB01280
00129*           3          COMMON /ALL/ IOPT(3),U,HL,H,Z,Y,XF,DELH,HF,CMAX,XMAX,RC,PDHX,HPRM PLB01290
00130*           4          DIMENSION ANOT(4), UA(14), CM(6,14), XM(6,14), HE(6,14), AD(6,14),PLB01300
00131*                     1 AH(6,14), ALP(20), CM2(6,14), XM2(6,14), HE2(6,14), AD2                          PLB01310
00132*                     2(6,14), AH2(6,14), UZ(6,14), PL(6), WI(6)                                         PLB01320
00133*           5          DATA UA /.5,.8,1.,1.5,2.,2.5,3.,4.,5.,7.,10.,12.,15.,20./                         PLB01330
00134*           6          DATA ANOT /'   ','(1)','(2)','(3)'/                                               PLB01340
00135*           7          IRD=5                                                                             PLB01350
00136*           8          IWRI=6                                                                            PLB01360
00137*           9          WRITE(IWRI,5432)                                                                  PLB01370
00138*          10    5432   FORMAT('1',21X,'PTPLU (VERSION 81036)'/22X,'AN IMPROVED POINT',                  PLB01380
00139*                     .' SOURCE SCREENING MODEL'/22X,'MODIFIED BY: JOE CATALANO AND ',                   PLB01390
00140*                     .'FRANK HALE'/22X,'AEROCOMP, INC. - COSTA MESA, CA      FOR THE'/                 PLB01400
00141*                     .22X,'ENVIRONMENTAL OPERATIONS BRANCH, EPA')                                       PLB01410
00142*                C        READ CARD TYPE 1, OPTIONS, TEMP, MX HT, AND RECEPTOR HT                       PLB01420
00143*          11          READ (IRD, * ) (IOPT(I),I=1,3),T,HL,Z                                            PLB01430
00144*                C        READ CARD TYPE 2, ANEMOMETER HT AND WIND SPEED EXPONENTS                      PLB01440
00145*          12          READ (IRD, * ) HANE,(PL(I),I=1,6)                                                 PLB01450
00146*                C        ENTRY POINT FOR CALCULATIONS OF ADDITIONAL SOURCES.                           PLB01460
00147*                C        READ CARD TYPE 3, OUTPUT HEADING                                              PLB01470
00148*          13    10    READ (IRD,430,END=400) ALP                                                        PLB01480
00149*                C        READ CARD TYPE 4, SOURCE INFORMATION                                          PLB01490
00150*          14          READ (IRD, * ,END=400) Q,HP,TS,VS,D                                               PLB01500
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00151*          15          DO 20 K=1,6                                                    PLB01510
00152*          16    20    WI(K)=(HP/HANE)**PL(K)                                         PLB01520
00153*                C        WI WILL BE USED TO CALCULATE THE WIND AT STACK TOP          PLB01530
00154*                C        THE FOLLOWING 3 STATEMENTS CHECK TO INSURE THE REASONABLENESS PLB01540
00155*                C        OF THE INPUT PARAMETERS.                                   PLB01550
00156*          17          IF (HL.LE.0.0) HL=5000.0                                       PLB01560
00157*          18          IF (Z.LE.0.0) Z=0.0                                            PLB01570
00158*          19          IF (Q.GT.0.) GO TO 530                                         PLB01580
00159*                C        CHECK ON EMISSION VALUE                                    PLB01590
00160*          20          WRITE (IWRI,410) Q                                             PLB01600
00161*          21          STOP                                                           PLB01610
00162*                C        IF NO AMBIENT AIR TEMP IS INPUT  293 KELVIN IS ASSUMED.    PLB01620
00163*          22    530   IF (T.EQ.0.) T=293.                                           PLB01630
00164*          23          VF=0.785398*VS*D*D                                             PLB01640
00165*                C        CALCULATE VOLUME FLOW  (VF)                                PLB01650
00166*                C        PRINT INITIAL INFORMATION                                  PLB01660
00167*          24          WRITE(IWRI,440)ALP                                             PLB01670
00168*          25          WRITE(IWRI,460)T,Q                                             PLB01680
00169*          26          WRITE(IWRI,461)HL,HP,IOPT(1),HANE,TS                           PLB01690
00170*          27          WRITE(IWRI,462)IOPT(2),(PL(I),I=1,3),VS                        PLB01700
00171*          28          WRITE(IWRI,463)IOPT(3),(PL(I),I=4,6),D,Z                       PLB01710
00172*          29          DELT=TS-T                                                      PLB01720
00173*                C        DELT (TEMPERATURE DIFFERENCE)                              PLB01730
00174*          30          F=3.1214*VF*DELT/TS                                            PLB01740
00175*                C        CALCULATE F (BUOYANCY FLUX PARAMETER)                      PLB01750
00176*                C        WRITE CALCULATED PARAMETERS.                               PLB01760
00177*          31          WRITE(IWRI,465)VF,F                                            PLB01770
00178*          32          WRITE (IWRI,470)ALP                                            PLB01780
00179*          33          PDHX=160.*F**0.33333                                           PLB01790
00180*                C        PDHX = PARTIAL DELH(X)                                     PLB01800
00181*                C        THIS EQUATION IS PART OF THAT IN BRIGGS(1969) P. 57        PLB01810
00182*                C        CHECK TO SEE IF BUOYANT OR MOMENTUM FLOW;STABLE OR UNSTABLE PLB01820
00183*          34          IF (TS.LT.T) GO TO 40                                          PLB01830
00184*          35          IF (F.GE.55.) GO TO 30                                         PLB01840
00185*                C        DETERMINE DELTA-T FOR BUOYANCY-MOMENTUM CROSSOVER (F<55) FOUND PLB01850
00186*                C        BY EQUATING BRIGGS(1969) EQ 5.2,PAGE 59 WITH COMBINATION OF PLB01860
00187*                C        BRIGGS (1971) EQUATIONS 6 AND 7, PAGE 1031 FOR F<55.       PLB01870
00188*          36          DTMB=0.0297*TS*VS**0.33333/D**0.66667                          PLB01880
00189*          37          IF (DELT.LT.DTMB) GO TO 40                                     PLB01890
00190*                C        THE FOLLOWING VARIABLES HAVE BEEN NORMALIZED WITH RESPECT TO U PLB01900
00191*                C              E.G. XFUN = FINAL DISTANCE (X) AS A FNCN OF U.       PLB01910
00192*                C        (0.049 IS 14*3.5/1000)BRIGGS(1971) EQUATION 7,F<55, AND    PLB01920
00193*                C        FINAL DISTANCE AS A FUNCTION OF U IS 3.5*XSTAR             PLB01930
00194*          38          XFUN=0.049*F**0.625                                            PLB01940
00195*                C        USED A COMBINATION OF BRIGGS(1971) EQNS. 6 AND 7, P. 1031 FOR PLB01950
00196*                C        F<55 - DHU IS AGAIN A FUNCTION OF WIND SPEED.              PLB01960
00197*          39          DHU=21.425*F**0.75                                             PLB01970
00198*          40          GO TO 50                                                       PLB01980
00199*                C        DETERMINE DELTA-T FOR BUOYANCY-MOMENTUM CROSSOVER (F>55)   PLB01990
00200*                C        FOUND BY EQUATING BRIGGS(1969) EQ. 5.2, PAGE 59 WITH       PLB02000
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00201*                  C       COMBINATION OF BRIGGS(1971) EQNS. 6 AND 7, PAGE 1031 FOR F>55.  PLB02010
00202*            41    30    DTMB=0.00575*TS*VS**0.66667/D**0.33333                           PLB02020
00203*            42          IF (DELT.LT.DTMB) GO TO 40                                       PLB02030
00204*                  C       DISTANCE TO FINAL BUOYANT RISE AS A FUNCTION OF U               PLB02040
00205*                  C         ( 0.119 = 34*3.5/100  )                                      PLB02050
00206*                  C       FROM BRIGGS(1971) EQN. 7, F>55, AND DISTANCE TO FINAL RISE IS  PLB02060
00207*                  C       3.5 XSTAR.                                                     PLB02070
00208*            43          XFUN=0.119*F**0.4                                                PLB02080
00209*                  C       USING A COMBINATION OF BRIGGS (1971) EQNS. 6 AND 7, PAGE 1031  PLB02090
00210*                  C       FOR F > 55.                                                    PLB02100
00211*            44          DHU=38.71*F**0.6                                                 PLB02110
00212*            45          GO TO 50                                                         PLB02120
00213*                  C       UNSTABLE-NEUTRAL MOMENTUM RISE FROM BRIGGS(1969) EQN.5.2, P.59 PLB02130
00214*                  C       NOTE: MOST ACCURATE WHEN VS/U>4  IT TENDS TO OVERESTIMATE RISE PLB02140
00215*                  C       WHEN VS/U<4  (SEE BRIGGS(1975) PAGE 78, FIG. 4)                PLB02150
00216*            46    40    XFUN=0.                                                          PLB02160
00217*            47          DHU=3.*VS*D                                                      PLB02170
00218*                  C       PREPARE PLUME RISE CALCULATIONS FOR STABLE CONDITIONS           PLB02180
00219*                  C       SE- STABILITY E     SF- STABILITY F                            PLB02190
00220*                  C       0.196123 = 9.80616 * 0.02                                      PLB02200
00221*            48    50    SE=0.196123/T                                                    PLB02210
00222*                  C       1.75 = 0.035/0.02                                              PLB02220
00223*            49          SF=1.75*SE                                                       PLB02230
00224*                  C       ME AND MF ARE INDICATORS FOR MOMENTUM PREDICTORS UNDER          PLB02240
00225*                  C       STABILITIES E AND F, RESPECTIVELY.                             PLB02250
00226*            50          ME=0                                                             PLB02260
00227*            51          MF=0                                                             PLB02270
00228*            52          IF (TS.LT.T) GO TO 60                                            PLB02280
00229*                  C       DETERMINE DELTA-T FOR BUOYANCY-MOMENTUM CROSSOVER (STABLE)     PLB02290
00230*                  C       FOUND BY EQUATING BRIGGS(1975) EQ. 59, PAGE 96 FOR STABLE      PLB02300
00231*                  C       BUOYANT RISE WITH BRIGGS(1969) EQ. 4.25, PAGE 59 .             PLB02310
00232*                  C            STABILITY E CALCULATIONS                                  PLB02320
00233*            53          DTMB=0.019582*T*VS*SQRT(SE)                                      PLB02330
00234*            54          IF (DELT.LT.DTMB) GO TO 60                                       PLB02340
00235*                  C       STABLE BUOYANT RISE  (DELTA-H WILL BE DETERMINED LATER IN THE  PLB02350
00236*                  C       PROGRAM AFTER THE WIND SPEED IS INPUT)(WIND WILL BE ALLOWED TO  PLB02360
00237*                  C       BE LOW ENOUGH TO REQUIRE STABLE RISE IN CALM CONDITIONS)        PLB02370
00238*                  C       BRIGGS(1975) EQ. 59,PAGE 96.                                   PLB02380
00239*            55          DHUTE=2.6*(F/SE)**0.33333                                        PLB02390
00240*            56          DHCAE=4.0*F**0.25/SE**0.375                                      PLB02400
00241*                  C     PLUME RISE UNDER CALM CONDITIONS, EQ 56 AND TOP P82 (BRIGGS 75)  PLB02410
00242*                  C     COMBINATION OF BRIGGS(1975) EQNS. 48 AND 59, DISTANCE TO FINAL   PLB02420
00243*                  C     RISE WILL BE DETERMINED AFTER THE WIND SPEED IS INTRODUCED.      PLB02430
00244*            57          XFOUSE=0.0020715/SQRT(SE)                                        PLB02440
00245*            58          GO TO 70                                                         PLB02450
00246*                  C     STABLE MOMENTUM RISE FOR E STABILITY                             PLB02460
00247*            59    60    ME=1                                                             PLB02470
00248*            60          DHAUE=3.*VS*D                                                    PLB02480
00249*                  C     THE FOLLOWING TWO EQNS. ARE TAKEN FROM BRIGGS EQNS. 4.28, P. 59-PLB02490
00250*                  C     DUM IS A DUMMY EXPRESSION USED IN CALCULATING DELTA-H.           PLB02500
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00251*                61          DUM=1.5*(VS*VS*D*D*T/(4.*TS))**0.33333                                  PLB02510
00252*                62          DUTE=DUM/SE**0.166667                                                   PLB02520
00253*                      C          F STABILITY CASE                                                   PLB02530
00254*                63    70    DTMB=0.019582*T*VS*SQRT(SF)                                             PLB02540
00255*                      C       THE FOLLOWING EXPRESSIONS ARE SIMILAR TO THOSE USED IN THE           PLB02550
00256*                      C       E-STABILITY SECTION.                                                PLB02560
00257*                64          IF (DELT.LT.DTMB) GO TO 80                                              PLB02570
00258*                65          DHUTF=2.6*(F/SF)**0.33333                                               PLB02580
00259*                66          DHCAF=4.0*F**0.25/SF**0.375                                             PLB02590
00260*                      C       PLUME RISE UNDER CALM CONDITIONS, EQ 56 AND TOP P82 (BRIGGS 75)      PLB02600
00261*                67          XFOUSF=0.0020715/SQRT(SF)                                               PLB02610
00262*                68          GO TO 90                                                                PLB02620
00263*                69    80    MF=1                                                                    PLB02630
00264*                70          DHAUF=3.*VS*D                                                           PLB02640
00265*                71          IF (ME.EQ.0) DUM=1.5*(VS*VS*D*D*T/(4.*TS))**0.33333                     PLB02650
00266*                72          DUTF=DUM/SF**0.166667                                                   PLB02660
00267*                73    90    DO 330 KST=1,6                                                          PLB02670
00268*                74          GO TO (100,110,120,130,140,150), KST                                    PLB02680
00269*                      C       SET DO LOOP LIMITS AND TEST TIME (THOUSANDS OF SECONDS) AS A         PLB02690
00270*                      C        FUNCTION OF STABILITY.                                             PLB02700
00271*                      C       IA AND IB ARE INDICIES WHICH RESTRICT THE WIND SPEEDS               PLB02710
00272*                      C       FOR EACH STABILITY CLASS. TM, THE TRAVEIL TIME OF THE PLUME, ISPLB02720
00273*                      C       THE MAXIMUM TIME A PLUME IS EXPECTED TO REMAIN AT A PARTICULAR      PLB02730
00274*                      C       STABILITY. THE LIMITS FOR EACH STABILITY CLASS ARE                  PLB02740
00275*                      C             A - 4 HOURS                                                   PLB02750
00276*                      C             B - 6 HOURS                                                   PLB02760
00277*                      C             C - 8 HOURS                                                   PLB02770
00278*                      C             D - UNLIMITED                                                 PLB02780
00279*                      C             E - 8 HOURS                                                   PLB02790
00280*                      C             F - 8 HOURS                                                   PLB02800
00281*                      C                                                                           PLB02810
00282*                75    100   IA=1                                                                    PLB02820
00283*                76          IB=7                                                                    PLB02830
00284*                77          TM=14.4                                                                 PLB02840
00285*                      C       14.4 IS EQUIVALENT TO 4 HOURS. (IN THOUSANDS OF SECONDS)            PLB02850
00286*                78          GO TO 160                                                               PLB02860
00287*                      C       STABILITY B (60)                                                    PLB02870
00288*                79    110   IA=1                                                                    PLB02880
00289*                80          IB=9                                                                    PLB02890
00290*                81          TM=21.6                                                                 PLB02900
00291*                      C       21.6 IS EQUIVALENT TO 6 HOURS.                                      PLB02910
00292*                82          GO TO 160                                                               PLB02920
00293*                      C       STABILITY C (70)                                                    PLB02930
00294*                83    120   IA=5                                                                    PLB02940
00295*                84          IB=13                                                                   PLB02950
00296*                85          TM=28.8                                                                 PLB02960
00297*                      C       28.8 IS EQUIVALENT TO 8 HOURS.                                      PLB02970
00298*                86          GO TO 160                                                               PLB02980
00299*                      C       STABILITY D (80)                                                    PLB02990
00300*                87    130   IA=1                                                                    PLB03000
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00301*          88              IB=14                                                   PLB03010
00302*          89              TM=999.                                                 PLB03020
00303*                  C          999. IS MORE THAN 24 HOURS SINCE THE MET CONDITIONS PRODUCING PLB03030
00304*                  C          D-STABILITY CAN PERSIST FOR EXTENDED PERIODS OF TIME.  PLB03040
00305*          90              GO TO 160                                               PLB03050
00306*                  C          STABILITY E (90)                                     PLB03060
00307*          91      140     IA=5                                                    PLB03070
00308*          92              IB=9                                                    PLB03080
00309*          93              TM=28.8                                                 PLB03090
00310*                  C          28.8 IS EQUIVALENT TO 8 HOURS.                       PLB03100
00311*          94              GO TO 160                                               PLB03110
00312*                  C          STABILITY F (100)                                    PLB03120
00313*          95      150     IA=5                                                    PLB03130
00314*          96              IB=9                                                    PLB03140
00315*                  C          TM IS STILL EQUAL TO 28.8 (8 HOURS).                 PLB03150
00316*                  C          CALCULATE FOR EACH APPROPRIATE WIND SPEED.           PLB03160
00317*          97      160     DO 240 I=IA,IB                                          PLB03170
00318*          98              U=UA(I)                                                 PLB03180
00319*                  C          DETERMINE  PLUME HEIGHT.                             PLB03190
00320*          99              CALL PH                                                 PLB03200
00321*         100              H=HF                                                    PLB03210
00322*                  C          DETERMINE MAXIMUM CONCENTRATION FOR THIS EFFECTIVE HEIGHT. PLB03220
00323*         101              CALL TPMX                                               PLB03230
00324*                  C          DETERMINE IF CAUTIONARY NOTES ARE NEEDED.            PLB03240
00325*         102              IF (CMAX.NE.9.999E+9) GO TO 170                         PLB03250
00326*         103              CM(KST,I)=CMAX                                          PLB03260
00327*         104              GO TO 180                                               PLB03270
00328*         105      170     CM(KST,I)=CMAX*Q                                        PLB03280
00329*         106      180     XM(KST,I)=XMAX                                          PLB03290
00330*         107              HE(KST,I)=H                                             PLB03300
00331*                  C          TI IS THE TRAVEL TIME FROM SOURCE TO DISTANCE OF MAX. PLB03310
00332*         108              TI=XMAX/U                                               PLB03320
00333*                  C          SECTION FOR CAUTIONARY MESSAGES.                     PLB03330
00334*                  C          INITIALIZE CAUTIONARY FLAGS.                         PLB03340
00335*         109              AH(KST,I) = ANOT(1)                                     PLB03350
00336*         110              AD(KST,I) = ANOT(1)                                     PLB03360
00337*                  C          TEST FOR EXCESSIVE TRAVEL TIME.                      PLB03370
00338*         111              IF(TI.GT.TM)AD(KST,I) = ANOT(2)                         PLB03380
00339*                  C          CHECK FOR DIST TO MAX GREATER THAN 100 KM.           PLB03390
00340*         112              IF(XMAX.LT.100.)GOTO200                                 PLB03400
00341*         113              CM(KST,I)=9.999E+9                                      PLB03410
00342*         114              XM(KST,I)=999.999                                       PLB03420
00343*         115              AD(KST,I)=ANOT(4)                                       PLB03430
00344*                  C          TEST FOR EFFECTIVE HEIGHT MORE THAN 200 M.           PLB03440
00345*         116      200     IF(H.GT.200.)AH(KST,I)=ANOT(3)                          PLB03450
00346*         117      240     CONTINUE                                                PLB03460
00347*                  C          END OF LOOP FOR EACH WIND SPEED.                     PLB03470
00348*                  C                                                               PLB03480
00349*                  C          DO-LOOP WITH WIND PROFILE EXPONENTS                  PLB03490
00350*                  C                                                               PLB03500
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00351*          118          DO 320 I=IA,IB                                                    PLB03510
00352*          119          U=UA(I)*WI(KST)                                                   PLB03520
00353*                   C      CALCULATE THE EFFECTIVE STACK HEIGHT                            PLB03530
00354*                   C      CALL THE PLUME RISE ROUTINE                                     PLB03540
00355*          120          CALL PH                                                           PLB03550
00356*          121          H=HF                                                              PLB03560
00357*                   C      CALCULATE MAXIMUM CNCENTRATION AND                              PLB03570
00358*                   C      LOCATE THE DISTANCE TO MAX CONCENTRATION FOR THIS               PLB03580
00359*                   C      WIND SPEED AND STABILITY BY CALLING TPMX                        PLB03590
00360*          122          CALL TPMX                                                         PLB03600
00361*          123          IF (CMAX.NE.9.999E+9) GO TO 250                                   PLB03610
00362*          124          CM2(KST,I)=CMAX                                                   PLB03620
00363*          125          GO TO 260                                                         PLB03630
00364*          126      250 CM2(KST,I)=CMAX*Q                                                 PLB03640
00365*          127      260 XM2(KST,I)=XMAX                                                   PLB03650
00366*          128          HE2(KST,I)=H                                                      PLB03660
00367*          129          UZ(KST,I)=U                                                       PLB03670
00368*          130          TI=XMAX/U                                                         PLB03680
00369*                   C      SECTION FOR CAUTIONARY MESSAGES.                                PLB03690
00370*                   C      INITIALIZE CAUTIONARY FLAGS.                                    PLB03700
00371*          131          AH2(KST,I) = ANOT(1)                                              PLB03710
00372*          132          AD2(KST,I) = ANOT(1)                                              PLB03720
00373*                   C      TEST FOR EXCESSIVE TRAVEL TIME.                                 PLB03730
00374*          133          IF(TI.GT.TM)AD2(KST,I) = ANOT(2)                                  PLB03740
00375*                   C      CHECK FOR DIST TO MAX GREATER THAN 100 KM.                      PLB03750
00376*          134          IF(XMAX.LT.100.)GOTO201                                           PLB03760
00377*          135          CM2(KST,I)=9.999E+9                                               PLB03770
00378*          136          XM2(KST,I)=999.999                                                PLB03780
00379*          137          AD2(KST,I)=ANOT(4)                                                PLB03790
00380*                   C      TEST FOR EFFECTIVE HEIGHT MORE THAN 200 M.                      PLB03800
00381*          138      201 IF(H.GT.200.)AH2(KST,I)=ANOT(3)                                   PLB03810
00382*          139      320 CONTINUE                                                          PLB03820
00383*                   C      END OF LOOP FOR EXTRAPOLATED WIND SPEEDS.                       PLB03830
00384*          140      330 CONTINUE                                                          PLB03840
00385*                   C      END OF LOOP FOR EACH STABILITY.                                 PLB03850
00386*                   C                                                                      PLB03860
00387*                   C      WRITE OUTPUT SUMMARY TABLE.                                     PLB03870
00388*          141          KST=1                                                             PLB03880
00389*          142          WRITE (IWRI,480)HANE                                              PLB03890
00390*          143          WRITE(IWRI,482)                                                   PLB03900
00391*          144          WRITE (IWRI,485)                                                  PLB03910
00392*          145          DO 340 N=1,7                                                      PLB03920
00393*          146          WRITE (IWRI,490) KST,UA(N),CM(KST,N),XM(KST,N),AD(KST,N),HE(KST,N)PLB03930
00394*                      1,AH(KST,N),UZ(KST,N),CM2(KST,N),XM2(KST,N),AD2(KST,N),HE2(KST,N),APLB03940
00395*                      2H2(KST,N)                                                         PLB03950
00396*          147      340 CONTINUE                                                          PLB03960
00397*          148          KST=2                                                             PLB03970
00398*          149          WRITE (IWRI,480)HANE                                              PLB03980
00399*          150          WRITE(IWRI,482)                                                   PLB03990
00400*          151          WRITE (IWRI,485)                                                  PLB04000
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00401*          152          DO 350 N=1,9                                                                    PLB04010
00402*          153          WRITE (IWRI,490) KST,UA(N),CM(KST,N),XM(KST,N),AD(KST,N),HE(KST,N)PLB04020
00403*                      1,AH(KST,N),UZ(KST,N),CM2(KST,N),XM2(KST,N),AD2(KST,N),HE2(KST,N),APLB04030
00404*                      2H2(KST,N)                                                                      PLB04040
00405*          154     350  CONTINUE                                                                       PLB04050
00406*          155          KST=3                                                                           PLB04060
00407*          156          WRITE (IWRI,480)HANE                                                            PLB04070
00408*          157          WRITE(IWRI,482)                                                                 PLB04080
00409*          158          WRITE (IWRI,485)                                                                PLB04090
00410*          159          DO 360 N=5,13                                                                   PLB04100
00411*          160          WRITE (IWRI,490) KST,UA(N),CM(KST,N),XM(KST,N),AD(KST,N),HE(KST,N)PLB04110
00412*                      1,AH(KST,N),UZ(KST,N),CM2(KST,N),XM2(KST,N),AD2(KST,N),HE2(KST,N),APLB04120
00413*                      2H2(KST,N)                                                                      PLB04130
00414*          161     360  CONTINUE                                                                       PLB04140
00415*          162          KST=4                                                                           PLB04150
00416*          163          WRITE (IWRI,480)HANE                                                            PLB04160
00417*          164          WRITE(IWRI,482)                                                                 PLB04170
00418*          165          WRITE (IWRI,485)                                                                PLB04180
00419*          166          DO 370 N=1,14                                                                   PLB04190
00420*          167          WRITE (IWRI,490) KST,UA(N),CM(KST,N),XM(KST,N),AD(KST,N),HE(KST,N)PLB04200
00421*                      1,AH(KST,N),UZ(KST,N),CM2(KST,N),XM2(KST,N),AD2(KST,N),HE2(KST,N),APLB04210
00422*                      2H2(KST,N)                                                                      PLB04220
00423*          168     370  CONTINUE                                                                       PLB04230
00424*          169          KST=5                                                                           PLB04240
00425*          170          WRITE (IWRI,480)HANE                                                            PLB04250
00426*          171          WRITE(IWRI,482)                                                                 PLB04260
00427*          172          WRITE (IWRI,485)                                                                PLB04270
00428*          173          DO 380 N=5,9                                                                    PLB04280
00429*          174          WRITE (IWRI,490) KST,UA(N),CM(KST,N),XM(KST,N),AD(KST,N),HE(KST,N)PLB04290
00430*                      1,AH(KST,N),UZ(KST,N),CM2(KST,N),XM2(KST,N),AD2(KST,N),HE2(KST,N),APLB04300
00431*                      2H2(KST,N)                                                                      PLB04310
00432*          175     380  CONTINUE                                                                       PLB04320
00433*          176          KST=6                                                                           PLB04330
00434*          177          WRITE (6,480)HANE                                                               PLB04340
00435*          178          WRITE(IWRI,482)                                                                 PLB04350
00436*          179          WRITE (6,485)                                                                   PLB04360
00437*          180          DO 390 N=5,9                                                                    PLB04370
00438*          181          WRITE (IWRI,490) KST,UA(N),CM(KST,N),XM(KST,N),AD(KST,N),HE(KST,N)PLB04380
00439*                      1,AH(KST,N),UZ(KST,N),CM2(KST,N),XM2(KST,N),AD2(KST,N),HE2(KST,N),APLB04390
00440*                      2H2(KST,N)                                                                      PLB04400
00441*          182     390  CONTINUE                                                                       PLB04410
00442*          183          WRITE (IWRI,500)                                                                PLB04420
00443*          184          WRITE (IWRI,510)                                                                PLB04430
00444*          185          WRITE (IWRI,520)                                                                PLB04440
00445*          186          GO TO 10                                                                        PLB04450
00446*          187     400  STOP                                                                           PLB04460
00447*                  C                                                                                   PLB04470
00448*          188     410  FORMAT (1X,' EMISSION OF ',F10.4,' G/SEC NOT ACCEPTABLE.'/'  ***              PLB04480
00449*                      1EXECUTION TERMINATED - CHECK INPUT DATA  *** ')                                PLB04490
00450*          189     430  FORMAT (20A4)                                                                  PLB04500
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00451*          190       440 FORMAT(/49X,'>>>INPUT PARAMETERS<<<'/' *** TITLE***  ',20A4)                    PLB04510
00452*          191       460 FORMAT(/1X,'***OPTIONS***',24X,                                                PLB04520
00453*                       1'***METEOROLOGY***',33X,'***SOURCE***'/1X,'IF = 1, USE OPTION',                  PLB04530
00454*                       219X,'AMBIENT AIR TEMPERATURE =',F9.2,' (K)',12X,                                 PLB04540
00455*                       3'EMISSION RATE =',F9.2,' (G/SEC)')                                               PLB04550
00456*          192       461  FORMAT(1X,'IF = 0, IGNORE OPTION',16X,'MIXING HEIGHT',11X,                     PLB04560
00457*                       5'=',F9.2,' (M)',12X,'STACK HEIGHT  =',F9.2,' (M)'/1X,                            PLB04570
00458*                       6'IOPT(1) = ',I1,' (GRAD PLUME RISE)',8X,'ANEMOMETER HEIGHT',                     PLB04580
00459*                       77X,'=',F9.2,' (M)',12X,'EXIT TEMP.     =',F9.2,' (K)')                           PLB04590
00460*          193       462  FORMAT(1X,'IOPT(2) = ',I1,' (STACK DOWNWASH)',9X,                              PLB04600
00461*                       9'WIND PROFILE EXPONENTS  = A:',F4.2,', B:',F4.2,', C:',                          PLB04610
00462*                       .F4.2,2X,'EXIT VELOCITY =',F9.2,' (M/SEC)')                                       PLB04620
00463*          194       463  FORMAT(1X,'IOPT(3) = ',I1,' (BUOY. INDUCED DISP.)',30X,                         PLB04630
00464*                       .'D:',F4.2,', E:',F4.2,', F:',F4.2,2X,'STACK DIAM.    =',                         PLB04640
00465*                       .F9.2,' (M)'/'0***RECEPTOR HEIGHT*** =',F9.2,' (M)')                              PLB04650
00466*          195       465  FORMAT  (/47X,'>>>CALCULATED PARAMETERS<<<',/1X,'VOLUMETRIC FLO','               PLB04660
00467*                       1W =',F9.2,' (M**3/SEC)',11X,'BUOYANCY FLUX PARAMETER =',F9.2,                    PLB04670
00468*                       2' (M**4/SEC**3)')                                                                PLB04680
00469*          196       470  FORMAT(//1X,20A4)                                                              PLB04690
00470*          197       480  FORMAT (1H0,20X,'****WINDS CONSTANT WITH HEIGHT****',                           PLB04700
00471*                       .9X,'****STACK TOP WINDS (EXTRAPOLATED FROM ',F5.1,' METERS)',                    PLB04710
00472*                       .'****')                                                                          PLB04720
00473*          198       482  FORMAT(' STABILITY',3X,'WIND SPEED',                                           PLB04730
00474*                       13X,'MAX CONC',3X,'DIST OF MAX',3X,' PLUME HT ',7X,'WIND SPEED',                  PLB04740
00475*                       23X,'MAX CONC',3X,'DIST OF MAX',3X,' PLUME HT')                                   PLB04750
00476*          199       485  FORMAT(15X,'(M/SEC)     (G/CU M)',7X,4H(KM),10X,3H(M),12X,                     PLB04760
00477*                       4'(M/SEC)     (G/CU M)',7X,4H(KM),10X,3H(M))                                    PLB04770
00478*          200       490  FORMAT (4X,I1,10X,F6.2,3X,1PE10.4,4X,0PF8.3,A3,1X,F8.1,A3,9X,                  PLB04780
00479*                       1F6.2,3X,1PE10.4,4X,0PF8.3,A3,1X,F8.1,A3)                                         PLB04790
00480*          201       500  FORMAT (1H0,' (1) THE DISTANCE TO THE POINT OF MAXIMUM CONCENTRATI               PLB04800
00481*                       1ON IS SO GREAT THAT THE SAME STABILITY IS NOT LIKELY'/1H ,                        PLB04810
00482*                       2'        TO PERSIST LONG ENOUGH FOR THE PLUME TO TRAVEL THIS FAR.'                PLB04820
00483*                       3)                                                                                PLB04830
00484*          202       510  FORMAT ('0 (2) THE PLUME IS CALCULATED TO BE AT A HEIGHT WHERE CAR               PLB04840
00485*                       1E SHOULD BE USED IN INTERPRETING THE COMPUTATION.')                              PLB04850
00486*          203       520  FORMAT (1H0,' (3) NO COMPUTATION WAS ATTEMPTED FOR THIS HEIGHT AS                PLB04860
00487*                       1THE POINT OF MAXIMUM CONCENTRATION IS GREATER THAN 100 KILOMETERS'               PLB04870
00488*                       2/1H ,'         FROM THE SOURCE.')                                                PLB04880
00489*                C                                                                                        PLB04890
00490*          204       END                                                                                  PLB04900
00491*                C                                                                                        PLB04910
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SYMBOL = = = = = = = = = = = = = = = = = = REFERENCES = = = = = = = = = = = = = = = = = =

10 - 13* 186
20 - 15 16*
30 - 35 41*
40 - 34 37 42 46*
50 - 40 45 48*
60 - 52 54 59*
70 - 58 63*
80 - 64 69*
90 - 68 73*
100 - 74 75*
110 - 74 79*
120 - 74 83*
130 - 74 87*
140 - 74 91*
150 - 74 95*
160 - 78 82 86 90 94 97*
170 - 102 105*
180 - 104 106*
200 - 112 116*
201 - 134 138*
240 - 97 117*
250 - 123 126*
260 - 125 127*
320 - 118 139*
330 - 73 140*
340 - 145 147*
350 - 152 154*
360 - 159 161*
370 - 166 168*
380 - 173 175*
390 - 180 182*
400 - 13RD 14RD 187*
410 - 20WR 188*
430 - 13RD 189*
440 - 24WR 190*
460 - 25WR 191*
461 - 26WR 192*
462 - 27WR 193*
463 - 28WR 194*
465 - 31WR 195*
470 - 32WR 196*
480 - 142WR 149WR 156WR 163WR 170WR 177WR 197*
482 - 143WR 150WR 157WR 164WR 171WR 178WR 198*
485 - 144WR 151WR 158WR 165WR 172WR 179WR 199*
490 - 146WR 153WR 160WR 167WR 174WR 181WR 200*
500 - 183WR 201*
510 - 184WR 202*
520 - 185WR 203*

530	-	19	22*								
5432	-	9WR	10*								
AD	-	4DI	110=	111=	115=	146WR	153WR	160WR	167WR	174WR	181WR
AD2	-	4DI	132=	133=	137=	146WR	153WR	160WR	167WR	174WR	181WR
AH	-	4DI	109=	116=	146WR	153WR	160WR	167WR	174WR	181WR	
AH2	-	4DI	131=	138=	146WR	153WR	160WR	167WR	174WR	181WR	
ALL	-	3CO									
ALP	-	4DI	13RD	24WR	32WR						
ANOT	-	4DI	6DA	109	110	111	115	116	131	132	133
		137	138								
CM	-	4DI	103=	105=	113=	146WR	153WR	160WR	167WR	174WR	181WR
CM2	-	4DI	124=	126=	135=	146WR	153WR	160WR	167WR	174WR	181WR
CMAX	-	3CO	102	103	105	123	124	126			
D	-	2CO	14RD	23	23	28WR	36	41	47	60	61
		61	70	71	71						
DELH	-	3CO									
DELT	-	29=	30	37	42	54	64				
DHAUE	-	2CO	60=								
DHAUF	-	2CO	70=								
DHCAE	-	2CO	56=								
DHCAF	-	2CO	66=								
DHU	-	2CO	39=	44=	47=						
DHUTE	-	2CO	55=								
DHUTF	-	2CO	65=								
DTMB	-	36=	37	41=	42	53=	54	63=	64		
DUM	-	61=	62	71=	72						
DUTE	-	2CO	62=								
DUTF	-	2CO	72=								
F	-	30=	31WR	33	35	38	39	43	44	55	56
		65	66								
H	-	3CO	100=	107	116	121=	128	138			
HANE	-	12RD	16	26WR	142WR	149WR	156WR	163WR	170WR	177WR	
HE	-	4DI	107=	146WR	153WR	160WR	167WR	174WR	181WR		
HE2	-	4DI	128=	146WR	153WR	160WR	167WR	174WR	181WR		
HF	-	3CO	100	121							
HL	-	3CO	11RD	17	17=	26WR					
HP	-	2CO	14RD	16	26WR						
HPRM	-	3CO									
I	-	11RD	11RD	12RD	12RD	27WR	27WR	28WR	28WR	97	98
		103	105	106	107	109	110	111	113	114	115
		116	118	119	124	126	127	128	129	131	132
		133	135	136	137	138					
IA	-	75=	79=	83=	87=	91=	95=	97	118		
IB	-	76=	80=	84=	88=	92=	96=	97	118		
IOPT	-	3CO	11RD	26WR	27WR	28WR					
IRD	-	7=	11RD	12RD	13RD	14RD					
IWR1	-	8=	9WR	20WR	24WR	25WR	26WR	27WR	28WR	31WR	32WR
		142WR	143WR	144WR	146WR	149WR	150WR	151WR	153WR	156WR	157WR
		158WR	160WR	163WR	164WR	165WR	167WR	170WR	171WR	172WR	174WR
		178WR	181WR	183WR	184WR	185WR					

K - 15 16 16

KST - 1CO 73 74 103 105 106 107 109 110 111
113 114 115 116 119 124 126 127 128 129
131 132 133 135 136 137 138 141= 146WR 146WR
146WR 146WR 146WR 146WR 146WR 146WR 146WR 146WR 146WR 146WR
148= 153WR 153WR 153WR 153WR 153WR 153WR 153WR 153WR 153WR
153WR 153WR 153WR 155= 160WR 160WR 160WR 160WR 160WR 160WR
160WR 160WR 160WR 160WR 160WR 160WR 162= 167WR 167WR 167WR
167WR 167WR 167WR 167WR 167WR 167WR 167WR 167WR 167WR 169=
174WR 174WR 174WR 174WR 174WR 174WR 174WR 174WR 174WR 174WR
174WR 174WR 176= 181WR 181WR 181WR 181WR 181WR 181WR 181WR
181WR 181WR 181WR 181WR 181WR

ME - 2CO 50= 59= 71

MF - 2CO 51= 69=

MH - 2CO

MS - 1CO

N - 145 146WR 146WR 146WR 146WR 146WR 146WR 146WR 146WR 146WR
146WR 146WR 146WR 152 153WR 153WR 153WR 153WR 153WR 153WR
153WR 153WR 153WR 153WR 153WR 153WR 159 160WR 160WR 160WR
160WR 160WR 160WR 160WR 160WR 160WR 160WR 160WR 160WR 166
167WR 167WR 167WR 167WR 167WR 167WR 167WR 167WR 167WR 167WR
167WR 167WR 173 174WR 174WR 174WR 174WR 174WR 174WR 174WR
174WR 174WR 174WR 174WR 174WR 174WR 180 181WR 181WR 181WR 181WR
181WR 181WR 181WR 181WR 181WR 181WR 181WR 181WR

PDHX - 3CO 33=

PH - 99 120

PL - 4DI 12RD 16 27WR 28WR

Q - 14RD 19 20WR 25WR 105 126

RC - 3CO

SE - 48= 49 53 55 56 57 62

SF - 49= 63 65 66 67 72

SQRT - 53 57 63 67

SY - 1CO

SZ - 1CO

T - 11RD 22 22= 25WR 29 34 48 52 53 61
63 71

TI - 108= 111 130= 133

TM - 77= 81= 85= 89= 93= 111 133

TPMX - 101 122

TS - 14RD 26WR 29 30 34 36 41 52 61 71

U - 3CO 98= 108 119= 129 130

UA - 4DI 5DA 98 119 146WR 153WR 160WR 167WR 174WR 181WR

UZ - 4DI 129= 146WR 153WR 160WR 167WR 174WR 181WR

VF - 23= 30 31WR

VS - 2CO 14RD 23 27WR 36 41 47 53 60 61
61 63 70 71 71

WI - 4DI 16= 119

X - 1CO

XF - 3CO

XFOUSE - 2CO 57=

XFOUSF	-	2CO	67=								
XFUN	-	2CO	38=	43=	46=						
XM	-	4DI	106=	114=	146WR	153WR	160WR	167WR	174WR	181WR	
XM2	-	4DI	127=	136=	146WR	153WR	160WR	167WR	174WR	181WR	
XMAX	-	3CO	106	108	112	127	130	134			
Y	-	3CO									
Z	-	3CO	11RD	18	18=	28WR					

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00492*          1           SUBROUTINE RCON                                                  PLB04920
00493*                    C                                                                  PLB04930
00494*                    C->->->->SECTION RCON.A - COMMON.                                  PLB04940
00495*          2           COMMON /MS/KST,X,SY,SZ                                           PLB04950
00496*          3           COMMON /ALL/IOPT(3),U,HL,H,Z,Y,XF,DELH,HF,CMAX,XMAX,RC,PDHX,HPRM PLB04960
00497*                    C                                                                  PLB04970
00498*                    C                                                                  PLB04980
00499*                    C->->->->SECTION RCON.B - EXPLANATIONS AND COMPUTATIONS             PLB04990
00500*                    C                          COMMON TO ALL CONDITIONS.               PLB05000
00501*                    C                                                                  PLB05010
00502*                    C  RCON DETERMINES RELATIVE CONCENTRATIONS, CHI/Q, FROM POINT SOURCES.  PLB05020
00503*                    C         RCON CALLS PSIG FOR THE DISPERSION COEFFICENTS.          PLB05030
00504*                    C        THE INPUT VARIABLES ARE:                                  PLB05040
00505*                    C         U  WIND SPEED (M/SEC)                                    PLB05050
00506*                    C         Z    RECEPTOR HEIGHT (M)                                 PLB05060
00507*                    C         H    EFFECTIVE STACK HEIGHT (M)                          PLB05070
00508*                    C         HL   MIXING HEIGHT- TOP OF NEUTRAL OR UNSTABLE LAYER(M). PLB05080
00509*                    C         X    DISTANCE RECEPTOR IS DOWNWIND OF SOURCE (KM)        PLB05090
00510*                    C         Y    DISTANCE RECEPTOR IS CROSSWIND FROM SOURCE (KM)     PLB05100
00511*                    C         KST  STABILITY CLASS                                     PLB05110
00512*                    C         DELH PLUME RISE(METERS)                                  PLB05120
00513*                    C        THE OUTPUT VARIABLES ARE....                              PLB05130
00514*                    C         SY     HORIZONTAL DISPERSION PARAMETER                   PLB05140
00515*                    C         SZ    VERTICAL DISPERSION PARAMETER                      PLB05150
00516*                    C         RC   RELATIVE CONCENTRATION (SEC/M**3) ,CHI/Q            PLB05160
00517*                    C         IWRI     OUTPUT UNIT CONTROL                             PLB05170
00518*          4           IWRI=6                                                           PLB05180
00519*                    C       THE FOLLOWING EQUATION IS SOLVED --                        PLB05190
00520*                    C       RC = (1/(2*PI*U*SIGMA Y*SIGMA Z))* (EXP(-0.5*(Y/SIGMA Y)**2))  PLB05200
00521*                    C          (EXP(-0.5*((Z-H)/SIGMA Z)**2) + EXP(-0.5*((Z+H)/SIGMA Z)**2)PLB05210
00522*                    C            PLUS THE SUM OF THE FOLLOWING 4 TERMS K TIMES (N=1,K) --  PLB05220
00523*                    C                 FOR NEUTRAL OR UNSTABLE CASES:                   PLB05230
00524*                    C              TERM 1- EXP(-0.5*((Z-H-2NL)/SIGMA Z)**2)            PLB05240
00525*                    C              TERM 2- EXP(-0.5*((Z+H-2NL)/SIGMA Z)**2)            PLB05250
00526*                    C              TERM 3- EXP(-0.5*((Z-H+2NL)/SIGMA Z)**2)            PLB05260
00527*                    C              TERM 4- EXP(-0.5*((Z+H+2NL)/SIGMA Z)**2)            PLB05270
00528*                    C NOTE THAT MIXING HEIGHT- THE TOP OF THE NEUTRAL OR UNSTABLE LAYER-  PLB05280
00529*                    C HAS A VALUE ONLY FOR STABILITIES 1-4, THAT IS, MIXING HEIGHT,    PLB05290
00530*                    C THE HEIGHT OF THE NEUTRAL OR UNSTABLE LAYER, DOES NOT EXIST FOR STABLEPLB05300
00531*                    C LAYERS AT THE GROUND SURFACE- STABILITY 5 OR 6.                  PLB05310
00532*                    C        THE ABOVE EQUATION IS SIMILAR TO EQUATION (5.8) P 36 IN   PLB05320
00533*                    C         WORKBOOK OF ATMOSPHERIC DISPERSION ESTIMATES WITH THE ADDITIONPLB05330
00534*                    C         OF THE EXPONENTIAL INVOLVING Y.                          PLB05340
00535*                    C       IF STABLE, SKIP CONSIDERATION OF MIXING HEIGHT.            PLB05350
00536*          5           IF (KST.GE.5) GO TO 50                                           PLB05360
00537*                    C       IF THE SOURCE IS ABOVE THE LID, SET RC = 0., AND RETURN.   PLB05370
00538*          6           IF (H.GT.HL) GO TO 20                                            PLB05380
00539*          7           IF (Z-HL) 50,50,40                                               PLB05390
00540*          8     20    IF (Z.LT.HL) GO TO 40                                            PLB05400
00541*          9           WRITE (IWRI,470)                                                 PLB05410
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00542*          10      40    RC=0.                                                          PLB05420
00543*          11            RETURN                                                         PLB05430
00544*                  C        IF X IS LESS THAN 1 METER, SET RC=0. AND RETURN.  THIS AVOIDS PLB05440
00545*                  C        PROBLEMS OF INCORRECT VALUES NEAR THE SOURCE.              PLB05450
00546*          12      50    IF (X.LT.0.001) GO TO 40                                       PLB05460
00547*                  C        CALL PSIG TO OBTAIN VALUES FOR SY AND SZ                   PLB05470
00548*          13            CALL PSIG                                                      PLB05480
00549*                  C        SY = SIGMA Y, THE STANDARD DEVIATION OF CONCENTRATION IN THE PLB05490
00550*                  C        Y-DIRECTION (M)                                            PLB05500
00551*                  C        SZ = SIGMA Z, THE STANDARD DEVIATION OF CONCENTRATION IN THE PLB05510
00552*                  C        Z-DIRECTION (M)                                            PLB05520
00553*                  C      IF IOPT(3) = 1, CONSIDER BUOYANCY INDUCED DISPERSION         PLB05530
00554*          14            IF (IOPT(3).EQ.0) GO TO 70                                     PLB05540
00555*          15            DUM=DELH/3.5                                                   PLB05550
00556*          16            IF(IOPT(1).EQ.0. .AND. X.LT.XF)DUM=PDHX*X**0.666667/(3.5*U)    PLB05560
00557*          17            DUM=DUM*DUM                                                    PLB05570
00558*          18            SY=SQRT(SY*SY+DUM)                                             PLB05580
00559*          19            SZ=SQRT(SZ*SZ+DUM)                                             PLB05590
00560*          20      70    C1=1.                                                          PLB05600
00561*          21            IF (Y.EQ.0.0) GO TO 100                                        PLB05610
00562*          22            YD=1000.*Y                                                     PLB05620
00563*                  C        YD IS CROSSWIND DISTANCE IN METERS.                        PLB05630
00564*          23            DUM=YD/SY                                                      PLB05640
00565*          24            TEMP=0.5*DUM*DUM                                               PLB05650
00566*          25            IF (TEMP.GE.50.) GO TO 40                                      PLB05660
00567*          26            C1=EXP(TEMP)                                                   PLB05670
00568*          27      100   IF (KST.GT.4) GO TO 120                                        PLB05680
00569*          28            IF (HL.LT.5000.) GO TO 200                                     PLB05690
00570*                  C        IF STABLE CONDITION OR UNLIMITED MIXING HEIGHT,            PLB05700
00571*                  C        USE EQUATION 3.2 IF Z = 0, OR EQ 3.1 FOR NON-ZERO Z.       PLB05710
00572*                  C        (EQUATION NUMBERS REFER TO WORKBOOK OF ATMOSPHERIC DISPERSION PLB05720
00573*                  C        ESTIMATES.)                                                PLB05730
00574*          29      120   C2=2.*SZ*SZ                                                    PLB05740
00575*          30            IF (Z) 40,130,150                                              PLB05750
00576*                  C      NOTE: AN ERRONEOUS NEGATIVE Z WILL RESULT IN ZERO CONCENTRATIONSPLB05760
00577*                  C                                                                   PLB05770
00578*                  C->->->->SECTION RCON.C - STABLE OR UNLIMITED MIXING, Z IS ZERO.    PLB05780
00579*                  C                                                                   PLB05790
00580*          31      130   C3=H*H/C2                                                      PLB05800
00581*          32            IF (C3.GE.50.) GO TO 40                                        PLB05810
00582*          33            A2=1./EXP(C3)                                                  PLB05820
00583*                  C        WADE EQUATION 3.2.                                         PLB05830
00584*          34            RC=A2/(3.14159*U*SY*SZ*C1)                                     PLB05840
00585*          35            RETURN                                                         PLB05850
00586*                  C                                                                   PLB05860
00587*                  C->->->->SECTION RCON.D - STABLE OR UNLIMITED MIXING, Z IS NON-ZERO. PLB05870
00588*                  C                                                                   PLB05880
00589*          36      150   A2=0.                                                          PLB05890
00590*          37            A3=0.                                                          PLB05900
00591*          38            CA=Z-H                                                         PLB05910
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00592*          39          CB=Z+H                                                          PLB05920
00593*          40          C3=CA*CA/C2                                                     PLB05930
00594*          41          C4=CB*CB/C2                                                     PLB05940
00595*          42          IF (C3.GE.50.) GO TO 170                                        PLB05950
00596*          43          A2=1./EXP(C3)                                                   PLB05960
00597*          44   170    IF (C4.GE.50.) GO TO 190                                        PLB05970
00598*          45          A3=1./EXP(C4)                                                   PLB05980
00599*               C        WADE EQUATION 3.1.                                           PLB05990
00600*          46   190    RC=(A2+A3)/(6.28318*U*SY*SZ*C1)                                 PLB06000
00601*          47          RETURN                                                          PLB06010
00602*               C                                                                    PLB06020
00603*               C->->->->SECTION RCON.E - UNSTABLE, ASSURED OF UNIFORM MIXING.       PLB06030
00604*               C                                                                    PLB06040
00605*               C        IF SIGMA-Z IS GREATER THAN 1.6 TIMES THE MIXING HEIGHT,     PLB06050
00606*               C        THE DISTRIBUTION BELOW THE MIXING HEIGHT IS UNIFORM WITH    PLB06060
00607*               C        HEIGHT REGARDLESS OF SOURCE HEIGHT OR RECEPTOR HEIGHT BECAUSE PLB06070
00608*               C        OF REPEATED EDDY REFLECTIONS FROM THE GROUND AND THE MIXING HT PLB06080
00609*          48   200    IF (SZ/HL.LE.1.6) GO TO 220                                     PLB06090
00610*               C        WADE EQUATION 3.5.                                           PLB06100
00611*          49          RC=1./(2.5066*U*SY*HL*C1)                                       PLB06110
00612*          50          RETURN                                                          PLB06120
00613*               C        INITIAL VALUE OF AN SET = 0.                                 PLB06130
00614*               C         AN - THE NUMBER OF TIMES THE SUMMATION TERM IS EVALUATED    PLB06140
00615*               C              AND ADDED IN.                                          PLB06150
00616*          51   220    AN=0.                                                           PLB06160
00617*          52          IF (Z) 40,380,230                                               PLB06170
00618*               C                                                                    PLB06180
00619*               C->->->->SECTION RCON.F - UNSTABLE, CALCULATE MULTIPLE EDDY          PLB06190
00620*               C                         REFLECTIONS, Z IS NON-ZERO.                PLB06200
00621*               C                                                                    PLB06210
00622*               C      STATEMENTS 220-260 CALCULATE RC, THE RELATIVE CONCENTRATION,  PLB06220
00623*               C        USING THE EQUATION DISCUSSED ABOVE.  SEVERAL INTERMEDIATE   PLB06230
00624*               C        VARIABLES ARE USED TO AVOID REPEATING CALCULATIONS.         PLB06240
00625*               C        CHECKS ARE MADE TO BE SURE THAT THE ARGUMENT OF THE         PLB06250
00626*               C        EXPONENTIAL FUNCTION IS NEVER GREATER THAN 50 (OR LESS THAN PLB06260
00627*               C        -50).                                                       PLB06270
00628*               C      CALCULATE MULTIPLE EDDY REFLECTIONS FOR RECEPTOR HEIGHT Z.    PLB06280
00629*          53   230    A1=1./(6.28318*U*SY*SZ*C1)                                      PLB06290
00630*          54          C2=2.*SZ*SZ                                                     PLB06300
00631*          55          A2=0.                                                           PLB06310
00632*          56          A3=0.                                                           PLB06320
00633*          57          CA=Z-H                                                          PLB06330
00634*          58          CB=Z+H                                                          PLB06340
00635*          59          C3=CA*CA/C2                                                     PLB06350
00636*          60          C4=CB*CB/C2                                                     PLB06360
00637*          61          IF (C3.GE.50.) GO TO 250                                        PLB06370
00638*          62          A2=1./EXP(C3)                                                   PLB06380
00639*          63   250    IF (C4.GE.50.) GO TO 270                                        PLB06390
00640*          64          A3=1./EXP(C4)                                                   PLB06400
00641*          65   270    SUM=0.                                                          PLB06410
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00642*          66          THL=2.*HL                                                   PLB06420
00643*          67    280   AN=AN+1.                                                    PLB06430
00644*          68          A4=0.                                                       PLB06440
00645*          69          A5=0.                                                       PLB06450
00646*          70          A6=0.                                                       PLB06460
00647*          71          A7=0.                                                       PLB06470
00648*          72          C5=AN*THL                                                   PLB06480
00649*          73          CC=CA-C5                                                    PLB06490
00650*          74          CD=CB-C5                                                    PLB06500
00651*          75          CE=CA+C5                                                    PLB06510
00652*          76          CF=CB+C5                                                    PLB06520
00653*          77          C6=CC*CC/C2                                                 PLB06530
00654*          78          C7=CD*CD/C2                                                 PLB06540
00655*          79          C8=CE*CE/C2                                                 PLB06550
00656*          80          C9=CF*CF/C2                                                 PLB06560
00657*          81          IF (C6.GE.50.) GO TO 300                                    PLB06570
00658*          82          A4=1./EXP(C6)                                               PLB06580
00659*          83    300   IF (C7.GE.50.) GO TO 320                                    PLB06590
00660*          84          A5=1./EXP(C7)                                               PLB06600
00661*          85    320   IF (C8.GE.50.) GO TO 340                                    PLB06610
00662*          86          A6=1./EXP(C8)                                               PLB06620
00663*          87    340   IF (C9.GE.50.) GO TO 360                                    PLB06630
00664*          88          A7=1./EXP(C9)                                               PLB06640
00665*          89    360   T=A4+A5+A6+A7                                               PLB06650
00666*          90          SUM=SUM+T                                                   PLB06660
00667*          91          IF (T.GE.0.01) GO TO 280                                    PLB06670
00668*          92          RC=A1*(A2+A3+SUM)                                           PLB06680
00669*          93          RETURN                                                      PLB06690
00670*                C                                                               PLB06700
00671*                C->->->->SECTION RCON.G - UNSTABLE, CALCULATE MULTIPLE EDDY      PLB06710
00672*                C                         REFLECTIONS, Z IS ZERO.               PLB06720
00673*                C                                                               PLB06730
00674*                C       CALCULATE MULTIPLE EDDY REFLECTIONS FOR GROUND LEVEL RECEPTOR PLB06740
00675*                C       HEIGHT.                                                 PLB06750
00676*          94    380   A1=1./(6.28318*U*SY*SZ*C1)                                 PLB06760
00677*          95          A2=0.                                                       PLB06770
00678*          96          C2=2.*SZ*SZ                                                 PLB06780
00679*          97          C3=H*H/C2                                                   PLB06790
00680*          98          IF (C3.GE.50.) GO TO 400                                    PLB06800
00681*          99          A2=2./EXP(C3)                                               PLB06810
00682*         100    400   SUM=0.                                                      PLB06820
00683*         101          THL=2.*HL                                                   PLB06830
00684*         102    410   AN=AN+1.                                                    PLB06840
00685*         103          A4=0.                                                       PLB06850
00686*         104          A6=0.                                                       PLB06860
00687*         105          C5=AN*THL                                                   PLB06870
00688*         106          CC=H-C5                                                     PLB06880
00689*         107          CE=H+C5                                                     PLB06890
00690*         108          C6=CC*CC/C2                                                 PLB06900
00691*         109          C8=CE*CE/C2                                                 PLB06910
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00692*          110            IF (C6.GE.50.) GO TO 430                                        PLB06920
00693*          111            A4=2./EXP(C6)                                                   PLB06930
00694*          112      430   IF (C8.GE.50.) GO TO 450                                        PLB06940
00695*          113            A6=2./EXP(C8)                                                   PLB06950
00696*          114      450   T=A4+A6                                                         PLB06960
00697*          115            SUM=SUM+T                                                       PLB06970
00698*          116            IF (T.GE.0.01) GO TO 410                                        PLB06980
00699*          117            RC=A1*(A2+SUM)                                                  PLB06990
00700*          118            RETURN                                                          PLB07000
00701*                    C                                                                    PLB07010
00702*                    C                                                                    PLB07020
00703*                    C***   SECTIONS OF SUBROUTINE RCON.                                  PLB07030
00704*                    C         SECTION RCON.A -  COMMON.                                  PLB07040
00705*                    C         SECTION RCON.B -  EXPLANATIONS AND COMPUTATIONS COMMON TO ALL PLB07050
00706*                    C                           CONDITIONS.                              PLB07060
00707*                    C         SECTION RCON.C -  STABLE OR UNLIMITED MIXING, Z IS ZERO.   PLB07070
00708*                    C         SECTION RCON.D -  STABLE OR UNLIMITED MIXING, Z IS NON-ZERO. PLB07080
00709*                    C         SECTION RCON.E -  UNSTABLE, ASSURED OF UNIFORM MIXING.     PLB07090
00710*                    C         SECTION RCON.F -  UNSTABLE, CALCULATE MULTIPLE EDDY        PLB07100
00711*                    C                           REFLECTIONS; Z IS NON-ZERO.              PLB07110
00712*                    C         SECTION RCON.G -  UNSTABLE, CALCULATE MULTIPLE EDDY        PLB07120
00713*                    C                           REFLECTIONS; Z IS ZERO.                  PLB07130
00714*                    C         SECTION RCON.H -  FORMAT.                                  PLB07140
00715*                    C                                                                    PLB07150
00716*                    C->->->->SECTION RCON.H - FORMAT                                     PLB07160
00717*          119      470   FORMAT (1HO,'BOTH H AND Z ARE ABOVE THE MIXING HEIGHT SO A RELIABLPLB07170
00718*                        1E COMPUTATION CAN NOT BE MADE.')                                PLB07180
00719*                    C                                                                    PLB07190
00720*          120            END                                                             PLB07200
00721*                    C                                                                    PLB07210
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SYMBOL		REFERENCES									
20	-	6	8*								
40	-	7	8	10*	12	25	30	32	52		
50	-	5	7	7	12*						
70	-	14	20*								
100	-	21	27*								
120	-	27	29*								
130	-	30	31*								
150	-	30	36*								
170	-	42	44*								
190	-	44	46*								
200	-	28	48*								
220	-	48	51*								
230	-	52	53*								
250	-	61	63*								
270	-	63	65*								
280	-	67*	91								
300	-	81	83*								
320	-	83	85*								
340	-	85	87*								
360	-	87	89*								
380	-	52	94*								
400	-	98	100*								
410	-	102*	116								
430	-	110	112*								
450	-	112	114*								
470	-	9WR	119*								
A1	-	53=	92	94=	117						
A2	-	33=	34	36=	43=	46	55=	62=	92	95=	99=
		117									
A3	-	37=	45=	46	56=	64=	92				
A4	-	68	82=	89	103=	111=	114				
A5	-	69=	84=	89							
A6	-	70=	86=	89	104=	113=	114				
A7	-	71=	88=	89							
ALL	-	3CO									
AN	-	51=	67=	67	72	102=	102	105			
C1	-	20=	26=	34	46	49	53	94			
C2	-	29=	31	40	41	54=	59	60	77	78	79
		80	96=	97	108	109					
C3	-	31=	32	33	40=	42	43	59=	61	62	97=
		98	99								
C4	-	41=	44	45	60=	63	64				
C5	-	72=	73	74	75	76	105=	106	107		
C6	-	77=	81	82	108=	110	111				
C7	-	78=	83	84							
C8	-	79=	85	86	109=	112	113				
C9	-	80=	87	88							
CA	-	38=	40	40	57=	59	59	73	75		

SUBROUTINE RCON

CB	-	39=	41	41	58=	60	60	74	76		
CC	-	73=	77	77	106=	108	108				
CD	-	74=	78	78							
CE	-	75=	79	79	107=	109	109				
CF	-	76=	80	80							
CMAX	-	3CO									
DELH	-	3CO	15								
DUM	-	15=	16=	17=	17	17	18	19	23=	24	24
EXP	-	26	33	43	45	62	64	82	84	86	88
		99	111	113							
H	-	3CO	6	31	31	38	39	57	58	97	97
		106	107								
HF	-	3CO									
HL	-	3CO	6	7	8	28	48	49	66	101	
HPRM	-	3CO									
IOPT	-	3CO	14	16							
IWRI	-	4=	9WR								
KST	-	2CO	5	27							
MS	-	2CO									
PDHX	-	3CO	16								
PSIG	-	13									
RC	-	3CO	10=	34=	46=	49=	92=	117=			
RCON	-	1EY									
SQRT	-	18	19								
SUM	-	65=	90=	90	92	100=	115=	115	117		
SY	-	2CO	18=	18	18	23	34	46	49	53	94
SZ	-	2CO	19=	19	19	29	29	34	46	48	53
		54	54	94	96	96					
T	-	89=	90	91	114=	115	116				
TEMP	-	24=	25	26							
THL	-	66=	72	101=	105						
U	-	3CO	16	34	46	49	53	94			
X	-	2CO	12	16	16						
XF	-	3CO	16								
XMAX	-	3CO									
Y	-	3CO	21	22							
YD	-	22=	23								
Z	-	3CO	7	8	30	38	39	52	57	58	

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00722*          1          SUBROUTINE TPMX
00723*                C    SUBROUTINE TPMX LOCATES THE DISTANCE TO MAX CONCENTRATION.          PLB07220
00724*                C    THE PROXIMITY OF THE MAXIMUM CONCENTRATION IS DETERMINED BY        PLB07230
00725*                C    SCREENING THE CALCULATED CONCENTRATIONS OF 16 PRESET DISTANCES.     PLB07240
00726*                C    THEN AN ITERATIVE PROCEDURE IS EMPLOYED TO PINPOINT THE            PLB07250
00727*                C    DISTANCE TO MAX CONCENTRATION TO WITHIN ONE METER.                 PLB07260
00728*          2          COMMON /MS/KST,X,SY,SZ                                             PLB07270
00729*          3          COMMON /ALL/IOPT(3),U,HL,H,Z,Y,XF,DELH,HF,CMAX,XMAX,RC,PDHX,HPRM   PLB07280
00730*          4          DIMENSION XV(16),DX1(16)                                           PLB07290
00731*          5          DATA XV/.1,.3,.5,.7,1.,2.,3.,5.,7.,10.,15.,20.,30.,40.,50.,100./   PLB07300
00732*          6          DATA DX1/4*-1.,5*-10.,6*-100.,100./                                PLB07310
00733*          7          DUM = DELH                                                         PLB07320
00734*          8          CMAX=0.                                                            PLB07330
00735*          9          RC=0.0                                                             PLB07340
00736*         10          Y=0.                                                               PLB07350
00737*         11          XMAX=0.0                                                           PLB07360
00738*                C         DO LOOP DETERMINING THE DISTANCE OF MAX CONC AMONG THE       PLB07370
00739*                C         FIXED DISTANCES.                                             PLB07380
00740*         12          DO 5 I =1,16                                                       PLB07390
00741*         13          X = XV(I)                                                          PLB07400
00742*                C        OPTION 1 EMPLOYS THE GRADUAL RISE ROUTINE                     PLB07410
00743*         14          IF(IOPT(1).EQ.0)GOTO15                                             PLB07420
00744*         15          DELH=DUM                                                           PLB07430
00745*         16          H=HF                                                               PLB07440
00746*         17          IF(X.GE.XF)GOTO15                                                  PLB07450
00747*         18          CALL PHX                                                           PLB07460
00748*         19     15   CALL RCON                                                          PLB07470
00749*         20          IF (.NOT.(H.GT.HL.AND.KST.LE.4)) GO TO 347                         PLB07480
00750*         21             CMAX = 0.                                                       PLB07490
00751*         22             XMAX = 0.                                                       PLB07500
00752*         23             RETURN                                                          PLB07510
00753*         24    347   CONTINUE                                                          PLB07520
00754*         25          IF(RC.LT.CMAX)GOTO5                                                PLB07530
00755*         26          CMAX=RC                                                            PLB07540
00756*         27          XMAX=X                                                             PLB07550
00757*         28          JB=I                                                               PLB07560
00758*         29     5    CONTINUE                                                           PLB07570
00759*                C       CMAX IS THE HIGHEST OF THE 16 CONCENTRATIONS OCCURRING          PLB07580
00760*                C        AT DISTANCE XMAX. JB IS THE INDEX (1-16) FOR THE MAX.         PLB07590
00761*         30          X=XMAX                                                             PLB07600
00762*                C       SET X EQUAL TO XMAX FOUND FROM PRESET X'S                       PLB07610
00763*         31          CLST=CMAX                                                          PLB07620
00764*         32          XLST=XMAX                                                          PLB07630
00765*                C       THE FOLLOWING INCREMENTS ARE USED:                              PLB07640
00766*                C          0.1 KM FOR X LESS THAN 1 KM                                  PLB07650
00767*                C          1.0 KM FOR X 1 KM TO 10 KM                                   PLB07660
00768*                C          10. KM FOR X 10 KM TO 100 KM                                 PLB07670
00769*         33          DX=DX1(JB)                                                         PLB07680
00770*         34     8    IF(ABS(DX).LE..001)RETURN                                          PLB07690
00771*                C        INCREMENT NOT ALLOWED TO BE LESS THAN 1 METER                  PLB07700
                                                                                            PLB07710
```

```
00772*          35          DX=-0.1*DX                                          PLB07720
00773*              C          REVERSE DIRECTIONS, REDUCE INCREMENT BY ONE-TENTH PLB07730
00774*              C          THE ITERATIVE PROCESS CONTINUES IN THIS MANNER   PLB07740
00775*              C          WITH CALCULATIONS GOING BACKWARDS AND FORWARDS   PLB07750
00776*              C          IN SMALLER AND SMALLER INCREMENTS UNTIL A 1      PLB07760
00777*              C          METER INTERVAL IS REACHED.                       PLB07770
00778*          36  9       IF(X.GT.100.)RETURN                                 PLB07780
00779*              C          IF X REACHES 100 KM CEASE COMPUTATIONS FOR THIS WIND SPEED. PLB07790
00780*          37          X=X+DX                                              PLB07800
00781*              C          OPTION 1 EMPLOYS GRADUAL PLUME RISE ROUTINE      PLB07810
00782*          38          IF(IOPT(1).EQ.0)GOTO7                               PLB07820
00783*          39          DELH=DUM                                            PLB07830
00784*          40          H=HF                                                PLB07840
00785*          41          IF(X.GE.XF)GOTO7                                    PLB07850
00786*          42          CALL PHX                                            PLB07860
00787*          43      7   CALL RCON                                           PLB07870
00788*          44          IF(RC.LE.CLST)GOTO50                                PLB07880
00789*              C          NEW CONCENTRATION IS HIGHER, KEEP GOING TO FIND MAX. PLB07890
00790*          45          CLST=RC                                             PLB07900
00791*          46          XLST=X                                              PLB07910
00792*          47          GOTO9                                               PLB07920
00793*          48      50  CMAX=CLST                                          PLB07930
00794*              C          NEW CONCENTRATION IS LOWER, RETURN TO REVERSE DIRECTIONS PLB07940
00795*          49          XMAX=XLST                                           PLB07950
00796*          50          CLST=RC                                             PLB07960
00797*          51          XLST=X                                              PLB07970
00798*          52          GOTO8                                               PLB07980
00799*          53          END                                                 PLB07990
00800*              C                                                           PLB08000
```

SYMBOL		REFERENCES									
5	-	12	25	29*							
7	-	38	41	43*							
8	-	34*	52								
9	-	36*	47								
15	-	14	17	19*							
50	-	44	48*								
347	-	20	24*								
ABS	-	34									
ALL	-	3CO									
CLST	-	31=	44	45=	48	50=					
CMAX	-	3CO	8=	21=	25	26=	31	48=			
DELH	-	3CO	7	15=	39=						
DUM	-	7=	15	39							
DX	-	33=	34	35=	35	37					
DX1	-	4D1	6DA	33							
H	-	3CO	16=	20	40=						
HF	-	3CO	16	40							
HL	-	3CO	20								
HPRM	-	3CO									
I	-	12	13	28							
IOPT	-	3CO	14	38							
JB	-	28=	33								
KST	-	2CO	20								
MS	-	2CO									
PDHX	-	3CO									
PHX	-	18	42								
RC	-	3CO	9=	25	26	44	45	50			
RCON	-	19	43								
SY	-	2CO									
SZ	-	2CO									
TPMX	-	1EY									
U	-	3CO									
X	-	2CO	13=	17	27	30=	36	37=	37	41	46
		51									
XF	-	3CO	17	41							
XLST	-	32=	46=	49	51=						
XMAX	-	3CO	11=	22=	27=	30	32	49=			
XV	-	4D1	5DA	13							
Y	-	3CO	10=								
Z	-	3CO									

```
00801*          1          SUBROUTINE PH                                                                PLB08010
00802*                C       ROUTINE FOR DETERMINING PLUME RISE.                                       PLB08020
00803*          2          COMMON /MS/ KST,X,SY,SZ                                                      PLB08030
00804*          3          COMMON /MH/ HP,VS,XFUN,DHU,ME,XFOUSE,DHUTE,DHAUE,DUTE,DHCAE,DHCAF,PLB08040
00805*                    1MF,XFOUSF,DHUTF,DHAUF,DUTF,D                                                PLB08050
00806*          4          COMMON /ALL/ IOPT(3),U,HL,H,Z,Y,XF,DELH,HF,CMAX,XMAX,RC,PDHX,HPRM PLB08060
00807*                C   THE FOLLOWING PARAMETERS ARE INPUT TO SUBROUTINE PH:                          PLB08070
00808*                C      DHAUE: DELTA-H*U  MOMENTUM RISE USING UNSTABLE RISE FOR E                 PLB08080
00809*                C      DHAUF:    "          "      "     "     "    "   "  F                    PLB08090
00810*                C      DHCAE: DELTA-H CALM BUOYANT RISE FOR E-STABILITY                          PLB08100
00811*                C      DHCAF:    "      "      "     "    F-STABILITY                           PLB08110
00812*                C      DHU: DELTA-H*U (UNSTABLE AND NEUTRAL)                                     PLB08120
00813*                C      DHUTE: DELTA-H*U**.3333 STABLE BUOYANT RISE FOR E                         PLB08130
00814*                C      DHUTF:    "     "    "      "      "     "    "  F                        PLB08140
00815*                C      DUTE: DELTA-H*U**.3333 STABLE MOMENTUM RISE FOR E                         PLB08150
00816*                C      DUTF:    "   "  "          "      "     "    "  F                        PLB08160
00817*                C      HP: PHYSICAL STACK HEIGHT (FROM CARD INPUT)                               PLB08170
00818*                C      ME: MOMENTUM INDICATOR FOR E-STABILITY                                    PLB08180
00819*                C      MF:     "          "    F-STABILITY                                       PLB08190
00820*                C      VS: STACK GAS VELOCITY (FROM CARD INPUT)                                  PLB08200
00821*                C      XFOUSE: DISTANCE TO STABLE BUOYANCY RISE/U FOR E                          PLB08210
00822*                C      XFOUSF:    "      "    "      "      "     "    "  F                      PLB08220
00823*                C      XFUN: DIST(KM) TO FINAL BUOYANT RISE (UNSTABLE AND NEUTRAL)               PLB08230
00824*                C                                                                                PLB08240
00825*                C   THE FOLLOWING PARAMETERS ARE OUTPUT FROM SUBROUTINE PH:                       PLB08250
00826*                C      XF: DISTANCE OF FINAL RISE                                                PLB08260
00827*                C      DELH: FINAL PLUME RISE                                                    PLB08270
00828*                C      HF: FINAL EFFECTIVE HEIGHT                                                PLB08280
00829*                C                                                                                PLB08290
00830*          5          HPRM=HP                                                                      PLB08300
00831*          6          IF (IOPT(2).EQ.0) GO TO 10                                                   PLB08310
00832*                C      OPTION FOR STACK DOWNWASH                                                 PLB08320
00833*          7          DUM=VS/U                                                                     PLB08330
00834*          8          IF (DUM.LT.1.5) HPRM=HP+2.*D*(DUM-1.5)                                       PLB08340
00835*          9          IF (HPRM.LT.0.) HPRM=0.                                                      PLB08350
00836*         10     10   GO TO (20,20,20,20,30,50), KST                                              PLB08360
00837*                C     NEUTRAL OR UNSTABLE                                                        PLB08370
00838*         11     20   XF=XFUN                                                                      PLB08380
00839*         12          DELH=DHU/U                                                                   PLB08390
00840*         13          HF=HPRM+DELH                                                                 PLB08400
00841*         14          RETURN                                                                       PLB08410
00842*                C         E STABILITY                                                            PLB08420
00843*         15     30   IF (ME.EQ.1) GO TO 40                                                        PLB08430
00844*         16          XF=XFOUSE*U                                                                  PLB08440
00845*         17          DELH=DHUTE/U**0.33333                                                        PLB08450
00846*         18          IF (DHCAE.LT.DELH) DELH=DHCAE                                                PLB08460
00847*                C      COMPARE CALC PLUME RISE WITH CALM WIND PLUME RISE                         PLB08470
00848*         19          HF=HPRM+DELH                                                                 PLB08480
00849*         20          RETURN                                                                       PLB08490
00850*                C      MOMENTUM RISE FOR E STABILITY                                             PLB08500
```

```
00851*          21      40    XF=0.                                                          PLB08510
00852*          22            DHA=DHAUE/U                                                    PLB08520
00853*          23            DELH=DUTE/U**0.33333                                           PLB08530
00854*          24            IF (DHA.LT.DELH) DELH=DHA                                      PLB08540
00855*          25            HF=HPRM+DELH                                                   PLB08550
00856*          26            RETURN                                                         PLB08560
00857*                    C       F STABILITY                                                PLB08570
00858*          27        50  IF (MF.EQ.1) GO TO 60                                         PLB08580
00859*          28            XF=XFOUSF*U                                                    PLB08590
00860*          29            DELH=DHUTF/U**0.33333                                          PLB08600
00861*          30            IF (DHCAF.LT.DELH) DELH=DHCAF                                  PLB08610
00862*                    C       COMPARE CALC PLUME RISE FOR CALM WIND PLUME RISE           PLB08620
00863*          31            HF=HPRM+DELH                                                   PLB08630
00864*          32            RETURN                                                         PLB08640
00865*                    C       MOMENTUM RISE FOR F STABILITY                              PLB08650
00866*          33        60  XF=0.                                                         PLB08660
00867*          34            DHA=DHAUF/U                                                    PLB08670
00868*          35            DELH=DUTF/U**0.33333                                           PLB08680
00869*          36            IF (DHA.LT.DELH) DELH=DHA                                      PLB08690
00870*          37            HF=HPRM+DELH                                                   PLB08700
00871*          38            RETURN                                                         PLB08710
00872*                    C                                                                  PLB08720
00873*          39            END                                                            PLB08730
00874*                    C                                                                  PLB08740
```

SYMBOL		REFERENCES									
10	- 6	10*									
20	- 10	10	10	10	11*						
30	- 10	15*									
40	- 15	21*									
50	- 10	27*									
60	- 27	33*									
ALL	- 400										
CMAX	- 400										
D	- 300	8									
DELH	- 400	12=	13	17=	18	18=	19	23=	24	24=	
	25	29=	30	30=	31	35=	36	36=	37		
DHA	- 22=	24	24	34=	36	36					
DHAUE	- 300	22									
DHAUF	- 300	34									
DHCAE	- 300	18	18								
DHCAF	- 300	30	30								
DHU	- 300	12									
DHUTE	- 300	17									
DHUTF	- 300	29									
DUM	- 7=	8	8								
DUTE	- 300	23									
DUTF	- 300	35									
H	- 400										
HF	- 400	13=	19=	25=	31=	37=					
HL	- 400										
HP	- 300	5	8								
HPRM	- 400	5=	8=	9	9=	13	19	25	31	37	
IOPT	- 400	6									
KST	- 200	10									
ME	- 300	15									
MF	- 300	27									
MH	- 300										
MS	- 200										
PDHX	- 400										
PH	- 1EY										
RC	- 400										
SY	- 200										
SZ	- 200										
U	- 400	7	12	16	17	22	23	28	29	34	35
VS	- 300	7									
X	- 200										
XF	- 400	11=	16=	21=	28=	33=					
XFOUSE	- 300	16									
XFOUSF	- 300	28									
XFUN	- 300	11									
XMAX	- 400										
Y	- 400										
Z	- 400										

```
00875*                1
00876*                      C     SUBROUTINE PHX                                                    PLB08750
00877*                2           THIS ROUTINE CALLED WHEN EMPLOYING THE GRADUAL RISE OPTION.       PLB08760
00878*                3     COMMON /MS/KST,X,SY,SZ                                                  PLB08770
00879*                      C     COMMON/ALL/IOPT(3),U,HL,H,Z,Y,XF,DELH,HF,CMAX,XMAX,RC,PDHX,HPRM   PLB08780
00880*                4           PDHX IS 160.*F**0.3333                                            PLB08790
00881*                5     DELH = PDHX*X**0.6666667/U                                              PLB08800
00882*                6     HX =HPRM + DELH                                                         PLB08810
00883*                7     IF (HX .LT. HF) H = HX                                                  PLB08820
00884*                8     RETURN                                                                  PLB08830
00885*                      C     END                                                               PLB08840
                                                                                                    PLB08850
```


SYMBOL			REFERENCES		
ALL	-	3CO			
CMAX	-	3CO			
DELH	-	3CO	4=	5	
H	-	3CO	6=		
HF	-	3CO	6		
HL	-	3CO			
HPRM	-	3CO	5		
HX	-	5=	6	6	
IOPT	-	3CO			
KST	-	2CO			
MS	-	2CO			
PDHX	-	3CO	4		
PHX	-	1EY			
RC	-	3CO			
SY	-	2CO			
SZ	-	2CO			
U	-	3CO	4		
X	-	2CO	4		
XF	-	3CO			
XMAX	-	3CO			
Y	-	3CO			
Z	-	3CO			

SUBROUTINE PSIG

```
00886*          1          SUBROUTINE PSIG                                                    PLB08860
00887*                C       VERTICAL DISPERSION PARAMETER VALUE, SZ DETERMINED BY          PLB08870
00888*                C        SZ = A * X ** B WHERE A AND B ARE FUNCTIONS OF BOTH STABILITY PLB08880
00889*                C        AND RANGE OF X.                                               PLB08890
00890*                C       HORIZONTAL DISPERSION PARAMETER VALUE, SY DETERMINED BY        PLB08900
00891*                C        LOGARITHMIC INTERPOLATION OF PLUME HALF-ANGLE ACCORDING TO    PLB08910
00892*                C        DISTANCE AND CALCULATION OF 1/2.15 TIMES HALF-ARC LENGTH.     PLB08920
00893*          2          COMMON /MS/KST,X,SY,SZ                                             PLB08930
00894*          3          DIMENSION XA(7), XB(2), XD(5), XE(8), XF(9), AA(8), BA(8), AB(3),  PLB08940
00895*                    1BB(3), AD(6), BD(6), AE(9), BE(9), AF(10), BF(10)                  PLB08950
00896*          4          DATA XA /.5,.4,.3,.25,.2,.15,.1/                                   PLB08960
00897*          5          DATA XB /.4,.2/                                                    PLB08970
00898*          6          DATA XD /30.,10.,3.,1.,.3/                                         PLB08980
00899*          7          DATA XE /40.,20.,10.,4.,2.,1.,.3,.1/                               PLB08990
00900*          8          DATA XF /60.,30.,15.,7.,3.,2.,1.,.7,.2/                            PLB09000
00901*          9          DATA AA /453.85,346.75,258.89,217.41,179.52,170.22,158.08,122.8/   PLB09010
00902*         10          DATA BA /2.1166,1.7283,1.4094,1.2644,1.1262,1.0932,1.0542,.9447/   PLB09020
00903*         11          DATA AB /109.30,98.483,90.673/                                     PLB09030
00904*         12          DATA BB /1.0971,0.98332,0.93198/                                   PLB09040
00905*         13          DATA AD /44.053,36.650,33.504,32.093,32.093,34.459/                PLB09050
00906*         14          DATA BD /0.51179,0.56589,0.60486,0.64403,0.81066,0.86974/          PLB09060
00907*         15          DATA AE /47.618,35.420,26.970,24.703,22.534,21.628,21.628,23.331,2PLB09070
00908*                    14.26/                                                              PLB09080
00909*         16          DATA BE /0.29592,0.37615,0.46713,0.50527,0.57154,0.63077,0.75660,0PLB09090
00910*                    1.81956,0.8366/                                                     PLB09100
00911*         17          DATA AF /34.219,27.074,22.651,17.836,16.187,14.823,13.953,13.953,1PLB09110
00912*                    14.457,15.209/                                                      PLB09120
00913*         18          DATA BF /0.21716,0.27436,0.32681,0.41507,0.46490,0.54503,0.63227,0PLB09130
00914*                    1.68465,0.78407,0.81558/                                            PLB09140
00915*         19          XY=X                                                               PLB09150
00916*         20          GO TO (10,40,70,80,110,140), KST                                   PLB09160
00917*                C       STABILITY A (10)                                                PLB09170
00918*         21     10    TH=(24.167-2.5334*ALOG(XY))/57.2958                                PLB09180
00919*         22          IF (X.GT.3.11) GO TO 170                                           PLB09190
00920*         23          DO 20 ID=1,7                                                       PLB09200
00921*         24          IF (X.GE.XA(ID)) GO TO 30                                          PLB09210
00922*         25     20    CONTINUE                                                          PLB09220
00923*         26          ID=8                                                               PLB09230
00924*         27     30    SZ=AA(ID)*X**BA(ID)                                                PLB09240
00925*         28          GO TO 190                                                          PLB09250
00926*                C       STABILITY B (20)                                                PLB09260
00927*         29     40    TH=(18.333-1.8096*ALOG(XY))/57.2958                                PLB09270
00928*         30          IF (X.GT.35.) GO TO 170                                            PLB09280
00929*         31          DO 50 ID=1,2                                                       PLB09290
00930*         32          IF (X.GE.XB(ID)) GO TO 60                                          PLB09300
00931*         33     50    CONTINUE                                                          PLB09310
00932*         34          ID=3                                                               PLB09320
00933*         35     60    SZ=AB(ID)*X**BB(ID)                                                PLB09330
00934*         36          GO TO 180                                                          PLB09340
00935*                C       STABILITY C (30)                                                PLB09350
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00936*          37      70    TH=(12.5-1.0857*ALOG(XY))/57.2958                 PLB09360
00937*          38            SZ=61.141*X**0.91465                              PLB09370
00938*          39            GO TO 180                                         PLB09380
00939*                  C        STABILITY D (40)                               PLB09390
00940*          40      80    TH=(8.3333-0.72382*ALOG(XY))/57.2958              PLB09400
00941*          41            DO 90 ID=1,5                                      PLB09410
00942*          42            IF (X.GE.XD(ID)) GO TO 100                        PLB09420
00943*          43      90    CONTINUE                                          PLB09430
00944*          44            ID=6                                              PLB09440
00945*          45      100   SZ=AD(ID)*X**BD(ID)                               PLB09450
00946*          46            GO TO 180                                         PLB09460
00947*                  C        STABILITY E (50)                               PLB09470
00948*          47      110   TH=(6.25-0.54287*ALOG(XY))/57.2958                PLB09480
00949*          48            DO 120 ID=1,8                                     PLB09490
00950*          49            IF (X.GE.XE(ID)) GO TO 130                        PLB09500
00951*          50      120   CONTINUE                                          PLB09510
00952*          51            ID=9                                              PLB09520
00953*          52      130   SZ=AE(ID)*X**BE(ID)                               PLB09530
00954*          53            GO TO 180                                         PLB09540
00955*                  C        STABILITY F (60)                               PLB09550
00956*          54      140   TH=(4.1667-0.36191*ALOG(XY))/57.2958              PLB09560
00957*          55            DO 150 ID=1,9                                     PLB09570
00958*          56            IF (X.GE.XF(ID)) GO TO 160                        PLB09580
00959*          57      150   CONTINUE                                          PLB09590
00960*          58            ID=10                                             PLB09600
00961*          59      160   SZ=AF(ID)*X**BF(ID)                               PLB09610
00962*          60            GO TO 180                                         PLB09620
00963*          61      170   SZ=5000.                                          PLB09630
00964*          62            GO TO 190                                         PLB09640
00965*          63      180   IF (SZ.GT.5000.) SZ=5000.                         PLB09650
00966*          64      190   SY=465.116*XY*SIN(TH)/COS(TH)                     PLB09660
00967*                  C        465.116 = 1000. (M/KM) / 2.15                  PLB09670
00968*          65            RETURN                                            PLB09680
00969*                  C                                                       PLB09690
00970*          66            END                                               PLB09700
```

SUBROUTINE PSIG

SYMBOL		REFERENCES									
10	-	20	21*								
20	-	23	25*								
30	-	24	27*								
40	-	20	29*								
50	-	31	33*								
60	-	32	35*								
70	-	20	37*								
80	-	20	40*								
90	-	41	43*								
100	-	42	45*								
110	-	20	47*								
120	-	48	50*								
130	-	49	52*								
140	-	20	54*								
150	-	55	57*								
160	-	56	59*								
170	-	22	30	61*							
180	-	36	39	46	53	60	63*				
190	-	28	62	64*							
AA	-	3DI	9DA	27							
AB	-	3DI	11DA	35							
AD	-	3DI	13DA	45							
AE	-	3DI	15DA	52							
AF	-	3DI	17DA	59							
ALOG	-	21	29	37	40	47	54				
BA	-	3DI	10DA	27							
BB	-	3DI	12DA	35							
BD	-	3DI	14DA	45							
BE	-	3DI	16DA	52							
BF	-	3DI	18DA	59							
COS	-	64									
ID	-	23	24	26=	27	27	31	32	34=	35	35
		41	42	44=	45	45	48	49	51=	52	52
		55	56	58=	59	59					
KST	-	2CO	20								
MS	-	2CO									
PSIG	-	1EY									
SIN	-	64									
SY	-	2CO	64=								
SZ	-	2CO	27=	35=	38=	45=	52=	59=	61=	63	63=
TH	-	21=	29=	37=	40=	47=	54=	64	64		
X	-	2CO	19	22	24	27	30	32	35	38	42
		45	49	52	56	59					
XA	-	3DI	4DA	24							
XB	-	3DI	5DA	32							
XD	-	3DI	6DA	42							
XE	-	3DI	7DA	49							
XF	-	3DI	8DA	56							
XY	-	19=	21	29	37	40	47	54	64		

SYMBOL - ========== ROUTINES IN WHICH THE SYMBOL IS USED ==========

A1	-	RCON			
A2	-	RCON			
A3	-	RCON			
A4	-	RCON			
A5	-	RCON			
A6	-	RCON			
A7	-	RCON			
AA	-	PSIG			
AB	-	PSIG			
ABS	-	TPMX			
AD	-	MAIN P	PSIG		
AD2	-	MAIN P			
AE	-	PSIG			
AF	-	PSIG			
AH	-	MAIN P			
AH2	-	MAIN P			
ALOG	-	PSIG			
ALP	-	MAIN P			
AN	-	RCON			
ANOT	-	MAIN P			
BA	-	PSIG			
BB	-	PSIG			
BD	-	PSIG			
BE	-	PSIG			
BF	-	PSIG			
C1	-	RCON			
C2	-	RCON			
C3	-	RCON			
C4	-	RCON			
C5	-	RCON			
C6	-	RCON			
C7	-	RCON			
C8	-	RCON			
C9	-	RCON			
CA	-	RCON			
CB	-	RCON			
CC	-	RCON			
CD	-	RCON			
CE	-	RCON			
CF	-	RCON			
CLST	-	TPMX			
CM	-	MAIN P			
CM2	-	MAIN P			
CMAX	-	MAIN P	TPMX		
COS	-	PSIG			
D	-	MAIN P	PH		
DELH	-	PH	PHX	RCON	TPMX
DELT	-	MAIN P			

DHA - PH
DHAUE - MAIN P PH
DHAUF - MAIN P PH
DHCAE - MAIN P PH
DHCAF - MAIN P PH
DHU - MAIN P PH
DHUTE - MAIN P PH
DHUTF - MAIN P PH
DTMB - MAIN P
DUM - MAIN P PH RCON TPMX
DUTE - MAIN P PH
DUTF - MAIN P PH
DX - TPMX
DX1 - TPMX
EXP - RCON
F - MAIN P
H - MAIN P PHX RCON TPMX
HANE - MAIN P
HE - MAIN P
HE2 - MAIN P
HF - MAIN P PH PHX TPMX
HL - MAIN P RCON TPMX
HP - MAIN P PH
HPRM - PH PHX
HX - PHX
I - MAIN P TPMX
IA - MAIN P
IB - MAIN P
ID - PSIG
IOPT - MAIN P PH RCON TPMX
IRD - MAIN P
IWRI - MAIN P RCON
JB - TPMX
K - MAIN P
KST - MAIN P PH PSIG RCON TPMX
ME - MAIN P PH
MF - MAIN P PH
N - MAIN P
PDHX - MAIN P PHX RCON
PH - MAIN P
PHX - TPMX
PL - MAIN P
PSIG - RCON
Q - MAIN P
RC - RCON TPMX
RCON - TPMX
SE - MAIN P
SF - MAIN P
SIN - PSIG
SQRT - MAIN P RCON

SUM	- RCON				
SY	- PSIG	RCON			
SZ	- PSIG	RCON			
T	- MAIN P	RCON			
TEMP	- RCON				
TH	- PSIG				
THL	- RCON				
TI	- MAIN P				
TM	- MAIN P				
TPMX	- MAIN P				
TS	- MAIN P				
U	- MAIN P	PH	PHX	RCON	
UA	- MAIN P				
UZ	- MAIN P				
VF	- MAIN P				
VS	- MAIN P	PH			
WI	- MAIN P				
X	- PHX	PSIG	RCON	TPMX	
XA	- PSIG				
XB	- PSIG				
XD	- PSIG				
XE	- PSIG				
XF	- PH	PSIG	RCON	TPMX	
XFOUSE	- MAIN P	PH			
XFOUSF	- MAIN P	PH			
XFUN	- MAIN P	PH			
XLST	- TPMX				
XM	- MAIN P				
XM2	- MAIN P				
XMAX	- MAIN P	TPMX			
XV	- TPMX				
XY	- PSIG				
Y	- RCON	TPMX			
YD	- RCON				
Z	- MAIN P	RCON			

****

I N D E X
END OF ANALYSIS
JPL FORTRAN V VERSION

APPENDIX C

SENSITIVITY ANALYSIS

This section presents a simple analysis designed to acquaint the user with the magnitude of changes expected in surface concentrations when certain model inputs are varied.

OPTIONS

PTPLU has three technical options: gradual plume rise, stack downwash, and buoyancy-induced dispersion. The effects of employing each of the options are discussed next, using as a base the calculation presented in Section 8.

Gradual Plume Rise

The gradual plume rise option alters the assumptions made about the height of the plume up to the distance of final rise. If the option is not employed, calculations are made as if the plume is always at the effective height. If the option is employed, the plume is assumed to rise gradually to the final height as the distance downwind increases. The effect of employing the option is to decrease the plume height between the point of release and the point of final rise, which results in higher ground-level concentrations.

In the example presented in Section 8, the maximum concentration occurs at a point beyond the distance of final rise (see Figure 7). Thus, the gradual plume rise option has no effect for stabilities B or D with a wind speed of 4 m/s. Despite the fact that the option has no effect on the maxima, it should be noted that in the process of searching for the maximum, the option affects calculations for locations between the source and the distance to final rise. Table C-1 shows the plume heights and concentrations with and without the option for some of the distances for which calculations were performed, for stability B with a wind speed of 4 m/s. It can be seen that beyond 0.6 km, which is the distance to final rise, the option has no effect. Also note in Figure 7 that the maximum concentration for stability A with a wind speed of 3.0 m/s is affected by the option, as this maximum occurs before final rise.

TABLE C-1. PLUME HEIGHTS AND CONCENTRATIONS WITH AND WITHOUT THE GRADUAL-RISE OPTION*

	With gradual rise		Without gradual rise	
Distance (km)	Height (m)	Conc. ($\mu g/m^3$)	Height (m)	Conc. ($\mu g/m^3$)
0.1	73.3	0	150.0	0
0.3	109.2	11	150.0	0
0.5	137.2	77	150.0	38
0.7	150.0	190	150.0	190

* For stability B and wind speed of 4 m/s.

Stack Downwash

The stack downwash option simulates lowering of the plume just after it leaves the stack, as a result of low pressures on the leeward side of the stack. The model carries out this simulation by using a modified value for the physical height, which lowers the effective height of the plume. Again, decreased plume height results in higher ground-level concentrations.

The stack downwash option is important if the exit velocity of the effluent is less than 1.5 times the wind speed. In the example considered here, the wind speed is only 4 m/s, while the stack gas velocity is 20 m/s; therefore stack downwash should have a minimal effect. As can be seen in Table C-2, this is the case. However, if the wind speed in this example was 15 m/s or greater, the option becomes important and should be implemented.

TABLE C-2. MAXIMUM CONCENTRATIONS WITH AND WITHOUT STACK DOWNWASH, FOR STABILITY CLASS D

With stack downwash		Without stack downwash	
Conc. ($\mu g/m^3$)	Distance to max. conc. (km)	Conc. ($\mu g/m^3$)	Distance to max. conc. (km)
204	1.64	198	1.67

Buoyancy-Induced Dispersion (BID)

Buoyancy-induced dispersion is estimated by an increase in the dispersion parameters proportional to the plume rise under the assumption that the more buoyant a plume, the more the buoyancy contributes to dispersion. In the two cases considered, this increase in the dispersion parameters results in an increase in the maximum ground-level concentrations. However, use of this option will not always produce higher concentrations. For stability A with a wind speed of 0.5 m/s, concentration is reduced 23%. In general, the effect of buoyancy-induced dispersion on concentration is negligible, except when the stack height is small compared with the plume rise (as in this example). It should be noted that multiple concentration peaks are possible when this option is used along with the gradual plume rise option.

TABLE C-3. MAXIMUM CONCENTRATIONS WITH AND WITHOUT BID

	With BID		Without BID	
Stability class	Conc. ($\mu g/m^3$)	Distance to max. conc. (km)	Conc. ($\mu g/m^3$)	Distance to max. conc. (km)
B	282	0.97	278	1.02
D	122	4.79	112	5.63

PLUME-RISE-RELATED PARAMETERS

Of several parameters that can influence plume rise, two are varied here. The results of these variations are discussed next.

Stack Gas Temperature

Sensitivity to variations in stack gas temperature was studied using the program's built-in sample test as a base. Figure C-1 shows the percent change in maximum concentration and the percent change in distance to maximum concentration resulting from decreases in stack gas temperature under three wind and stability conditions. These results are also presented in Tables C-4 and C-5 with an additional wind and stability condition analyzed.

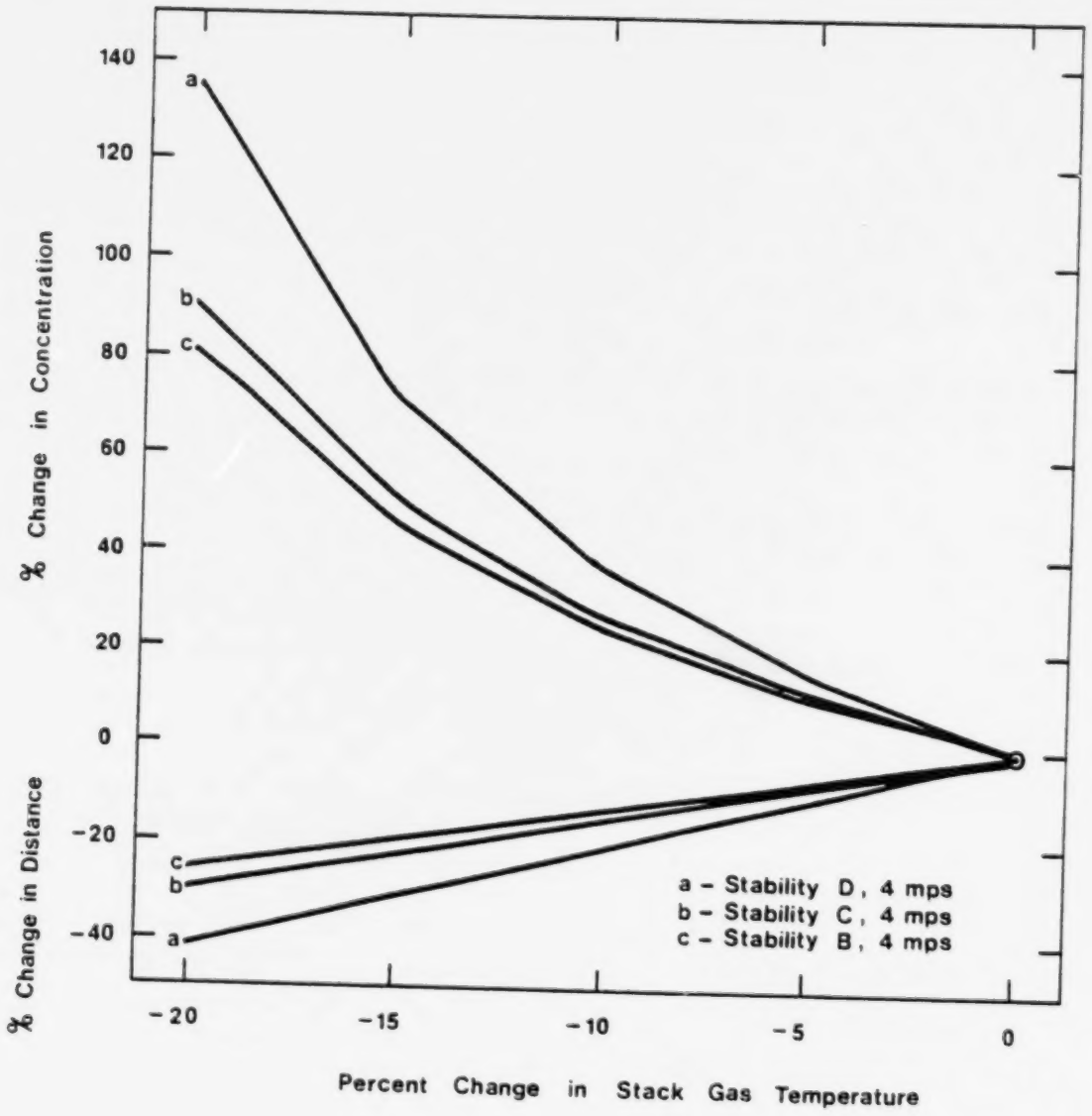

Figure C-1. Sensitivity of maximum concentration and distance-to-maximum to changes in stack gas temperature.

TABLE C-4. PERCENT INCREASE IN MAXIMUM CONCENTRATION WITH DECREASING STACK GAS TEMPERATURE

Stability class	Wind (m/s)	Decrease in stack gas temperature			
		5%	10%	15%	20%
B	4.0	10.26	24.57	45.95	81.70
C	4.0	11.08	26.66	50.21	90.22
C	2.0	12.91	31.69	61.35	115.04
D	4.0	15.01	36.97	71.93	135.35

TABLE C-5. PERCENT DECREASE IN DISTANCE TO MAXIMUM CONCENTRATION WITH DECREASING STACK GAS TEMPERATURE

Stability class	Wind (m/s)	Decrease in stack gas temperature			
		5%	10%	15%	20%
B	4.0	-4.70	-10.17	-16.83	-25.23
C	4.0	-5.47	-11.88	-19.52	-29.02
C	2.0	-6.47	-14.30	-23.22	-34.22
D	4.0	-9.13	-19.37	-30.85	-41.94

From Tables C-4 and C-5, it is apparent that decreased stack gas temperature, which makes the plume less buoyant, generally results in a higher maximum closer to the source. The specific changes, however, also depend on the stability and wind speed.

Stack Gas Velocity

Sensitivity to variation in stack gas velocity was studied using the built-in sample test as a base. Tables C-6 and C-7 show the percent change in maximum concentration and the percent change in distance to maximum concentration resulting from decreases in stack gas velocity under four wind and stability conditions. Figure C-2 graphically depicts some of these changes. It is apparent from Tables C-6 and C-7 and Figure C-2 that decreased stack gas velocity, which decreases plume rise, generally results in higher maximum concentrations closer to the source. However, the specific change in the results depends on the stability and wind speed as well. In general, for a given stability, higher wind speed counters the effect of increasing the stack gas velocity.

TABLE C-6. PERCENT INCREASE IN MAXIMUM CONCENTRATION WITH DECREASING STACK GAS VELOCITY

Stability class	Wind (m/s)	Decrease in stack gas velocity			
		5%	10%	15%	20%
B	4.0	4.14	8.66	13.59	19.00
C	4.0	4.46	9.33	14.68	25.58
C	2.0	5.15	10.85	17.19	24.28
D	4.0	5.98	12.62	20.00	28.30

TABLE C-7. PERCENT DECREASE IN DISTANCE TO MAXIMUM CONCENTRATION WITH DECREASING STACK GAS VELOCITY

Stability class	Wind (m/s)	Decrease in stack gas velocity			
		5%	10%	15%	20%
B	4.0	-1.94	-3.99	-6.04	-8.15
C	4.0	-2.30	-4.65	-7.05	-9.55
C	2.0	-2.68	-5.78	-8.64	-11.52
D	4.0	-3.95	-7.88	-11.85	-15.68

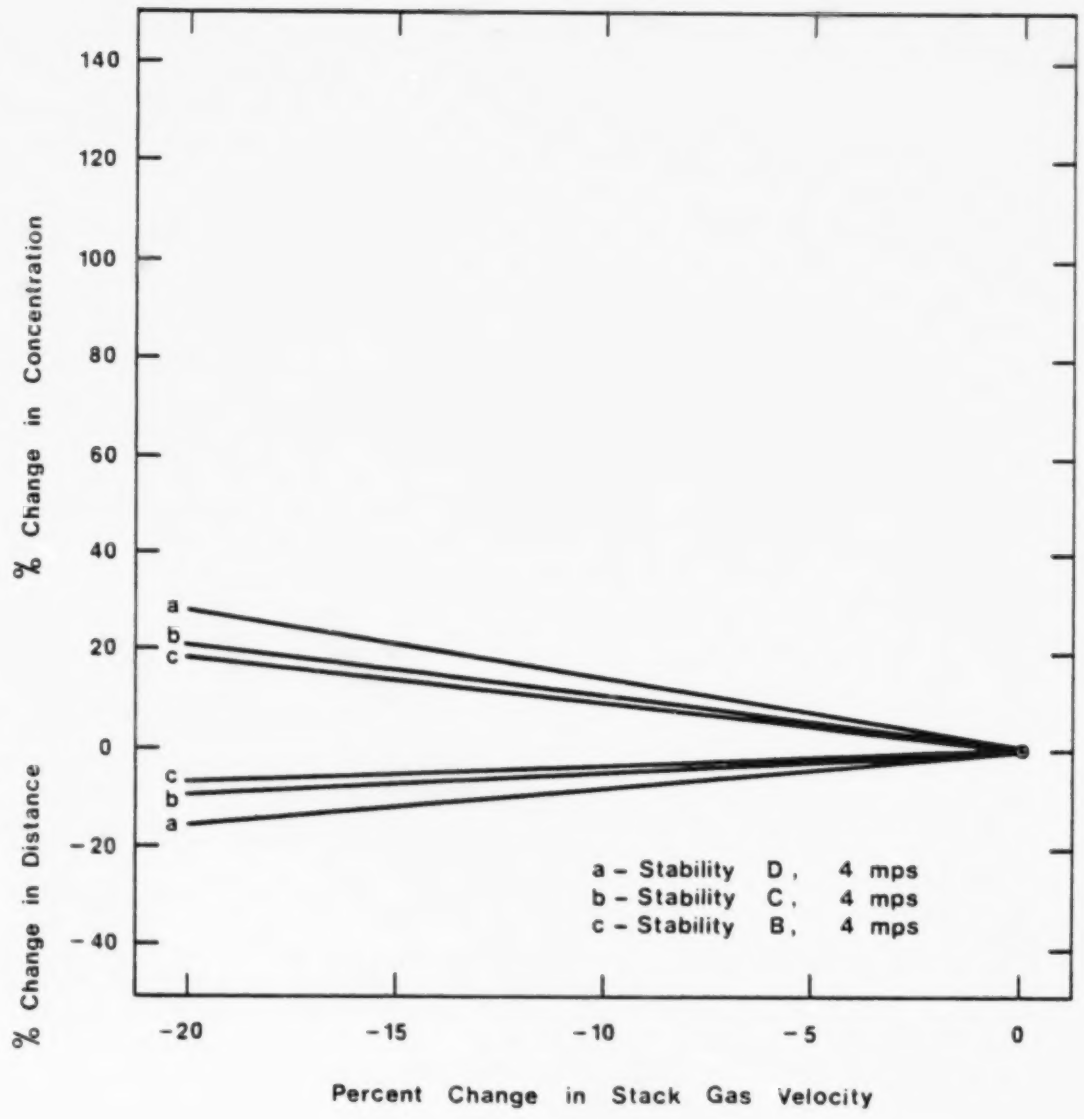

Figure C-2. Sensitivity of maximum concentration and distance-to-maximum to changes in stack gas velocity.

GLOSSARY

Some of the following definitions are taken from "Glossary of Meteorology," Ralph E. Huschke, editor. American Meteorological Society, Boston. 1959. 638 pp.

ADIABATIC PROCESS--A thermodynamic change of state of a system in which there is no transfer of heat or mass across the boundaries of the system. In an adiabatic process, compression always results in warming, expansion in cooling.

ADVECTION--The process of transport of an atmospheric property solely by the mass motion (velocity field) of the atmosphere. Refers to predominantly horizontal large-scale motions of the atmosphere.

AIR MASS--A widespread body of air that is approximately homogeneous in its horizontal and vertical properties, particularly with reference to temperature and moisture distribution.

ATMOSPHERIC STABILITY--State of the atmosphere with respect to vertical motions. Atmospheric conditions may be classified as stable, neutral, or unstable. In stable conditions, the potential temperature increases with height, and vertical motions are inhibited. Under these conditions, pollutants emitted at the ground tend to accumulate, while effluents from elevated sources normally remain aloft for long distances. In unstable conditions, the potential temperature decreases with height, and vertical motions are enhanced. Low-level emissions are dispersed rapidly upward, and high-level emissions are dispersed rapidly in the vertical. Elevated sources frequently make their maximum contribution to short-term ambient pollutant concentrations under unstable conditions. Between stable and unstable conditions is the situation in which the vertical temperature profile decreases nearly adiabatically. This condition, called "neutral stability," is quite frequent in most locations. For sources with tall stacks, the high wind speed neutral condition suppresses plume rise, and high ground-level concentrations are often observed. For ground-level emissions, near-neutral conditions usually result in concentrations between those for stable and unstable conditions.

BUOYANCY FLUX--A parameter related to the buoyant vertical motions of a released volume of effluent due to its excess of temperature over the surrounding air.

CONING--Spreading to produce a cone-shaped plume with its apex at the source. This usually occurs under windy conditions, and when the vertical temperature is near dry adiabatic or somewhat subadiabatic.

DOWNWASH--Rapid mixing downward of a plume by strong winds; usually observed in the lee of buildings and stacks.

DRY ADIABATIC LAPSE RATE--The rate of decrease of temperature with height of a parcel of dry air lifted adiabatically to lower pressures; 9.8°C/km.

EFFECTIVE STACK HEIGHT--The physical stack height plus plume rise. The point above the ground at which the gaseous effluent becomes essentially level.

ELEVATED INVERSION--An inversion layer above the ground surface that inhibits the dispersion of buoyant plumes. Elevated inversions are initiated by subsiding air from upper atmospheric levels or are the transitional zones between dissimilar air masses. Elevated inversions can also result from radiation inversions (which start at the surface) that are partially eliminated from below, due to surface heating.

FANNING--Spreading of a plume to give the appearance of a fan spread horizontally. This occurs under stable conditions when the vertical dispersion is greatly suppressed due to the vertical thermal structure but does not impede horizontal direction variations.

FUMIGATION--The rapid mixing downward to the ground of material previously emitted into a stable layer. Commonly occurs when the nocturnal temperature inversion is rapidly dissipated by solar heating of the surface; also occurs in sea breeze circulations during late morning or early afternoon.

INSOLATION--Incoming solar radiation received at the earth's surface.

INVERSION--A layer of air in which temperature increases with altitude; that is, inverted with respect to the more usual decrease of temperature with altitude.

LAPSE RATE--Adiabatic lapse rate is the rate of temperature change with height of a parcel displaced vertically in the atmosphere adiabatically. The parcel becomes cooler with lifting as it expands upon encountering less pressure;

conversely, the parcel becomes warmer with descent as it is compressed due to higher pressures. The adiabatic lapse rate is a decrease of about 1°C/100 m rise. When the temperature structure of the atmosphere (the environmental lapse rate) is subadiabatic (i.e., cooling is less rapid with height than the adiabatic rate), the atmosphere damps out vertical motion. When the temperature structure is superadiabatic, (i.e., cooling with height is more rapid than the adiabatic rate), rising parcels continue to accelerate upward. When the environmental lapse rate is near the dry adiabatic rate, vertical motions are neither damped out nor enhanced.

LOFTING--Upward spreading of the plume in the vertical above the plume centerline, but minimum spreading downward, because the plume is unable to penetrate an inversion below the plume centerline.

LOOPING--Plume spreading with the instantaneous appearance of large loops; the emitted plume is caught in thermals and rises, and a few seconds later, the newly emitted plume is caught in descending air and moves downward from the point of emission. Occurs in strongly unstable air; usually, the vertical thermal structure is superadiabatic near the ground.

MIXING HEIGHT--Height of the unstable or neutral layer that is well-mixed. Usually the height of the first significant inversion above the surface delimits the depth available for vertical dispersion of pollutants.

NOCTURNAL INVERSION--Surface-based inversion induced by radiational cooling.

PHYSICAL STACK HEIGHT--Actual height (above ground) of a stack or effluent source.

PLUME RISE--The height of a plume centerline above the point of release at a distance downwind from a source due to buoyancy and momentum effects. (The height above the point of release where the plume becomes level is the final plume rise.)

SUBSIDENCE INVERSION--A temperature inversion produced by the adiabatic warming of a layer of descending air. Results in a limited mixing volume below the subsiding layer.

SURFACE-BASED INVERSION--An inversion layer of stable air close to the ground, usually a radiation inversion. Inhibits dispersion of low-level releases of fugitive dust and other pollutants.

SURFACE BOUNDARY LAYER--The thin layer of air immediately above the earth's surface. (In this layer, shearing stresses are nearly constant.)

SURFACE ROUGHNESS--Irregularities in or on the earth's surface that increase mechanical turbulence and enhance pollutant dispersion.

TRAPPING--Plume spreading is moderate to rapid near the point of emission, but is impeded vertically (trapped) by an elevated stable layer. Usually, thermal conditions in the lower layer are adiabatic or subadiabatic.

Date_____

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Meteorology and Assessment Division (MD-80)
U. S. Environmental Protection Agency
Research Triangle Park, NC 27711

I would like to receive future revisions to the "PTPLU User's Guide."

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